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Groundwater/Vadose Zone Integration Project Science and Technology Summary Description

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PREFACE

The Hanford Site Groundwater/Vadose Zone Integration Project (Integration Project) was established in 1997 to develop the technical capability and scientific information needed to perform sitewide assessments of the potential effects of Hanford Site soil and groundwater contaminants on people and ecological systems. The risk assessment methodologies, computer models, and data developed by the Integration Project will help inform and influence key decisions made by regulators and the U.S. Department of Energy (DOE) on the selection of cleanup goals and remedies. To complete this mission, gaps in scientific understanding and technologies were identified, and research to close those gaps has been initiated. Background information on the Integration Project can be found at the following web site: http://www.bhi-erc.com/vadose.

The Integration Project science and technology mission will be accomplished consistent with the schedule for implementing key remediation decisions at the Hanford Site. Examples of the contributions science and technology will make over the longer term include quantifying and reducing the uncertainties in inventory estimates used in the sitewide risk assessment, testing and evaluating simplifying assumptions made in the sitewide assessments, describing the mechanisms for contaminant transport associated with high-level waste tanks that have leaked to the ground, and developing methods and data to reduce the uncertainty in ecological and human-health risk assessments. These contributions will be used to support decisions affecting the extent of single-shell tank waste retrieval needed and final closure of tank farms, as well as remediation of other waste sites at the Hanford Site.

The science and technology endeavor also provides near-term benefits to the Hanford Site by supporting decisions regarding whether interim corrective measures are needed to prevent tank farm contaminants from migrating through the vadose zone to the groundwater. The science and technology endeavor is conducting work to determine how tank-leak contaminants have altered the mineralogy of the subsurface; evaluate the potential for these contaminants to continue migrating; and perform nonisothermal, multiphase, reactive transport modeling of the tank leaks. These efforts will be used to support characterization and modeling efforts by the River

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Protection Project, and the science and technology endeavor will provide direct input to their characterization report.

This summary document describes the current status of the science and technology endeavor and the plans for future work to support the Integration Project and the Hanford Site. The science and technology investments will continue to evolve, based on the work that is funded and performed, and planned additions to the roadmap to include other technical areas such as remediation and monitoring.

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ACRONYMS

ACPC	Accelerated Paths to Closure
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CMS	Corrective Measures Study
CRCIA	*Columbia river Comprehensive Impact Assessment*
DNAPL	dense non-aqueous phase liquid
DOE	U. S. Department of Energy
EIS	Environmental Impact Statement
EMSP	Environmental Management Science Program
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERC	Environmental Restoration Contractor
FY	fiscal year
GW/VZ	Groundwater/Vadose Zone
HDW	Hanford Defined Waste
HLW	High-Level Waste
ILAW	immobilized low activity waste
IRM	Interim Response Measure
ITRD	Innovative Treatment Remediation Demonstration
LLW	Low-Level Waste
LRP	*Long Range Plan*
ORP	Office of River Protection
OST	Office of Science and Technology
PA	Performance Assessment
PFP	Plutonium Finishing Plant
PUREX	Plutonium Uranium Extraction
RCRA	*Resource Conservation and Recovery Act*
REDOX	reduction oxidation
RFI	Remedial Feasibility Investigation
RPE	Retrieval Performance Evaluation
RPP	River Protection Project
S&T	Science and Technology
SAC	System Assessment Capability
SCFA	Subcon Focus Area
SST	single-shell tank
STCG	Science and Technology Coordination Group
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TRU	transuranic
TSCA	*Toxic Substances Control Act of 1976*
WMA	Waste Management Area

1.0 INTRODUCTION

This volume of the Project Description for the Groundwater/Vadose Zone (GW/VZ) Integration Project contains the Science and Technology (S&T) roadmap. Roadmapping is a process in which problem holders (such as the U.S. Department of Energy [DOE], Tribal Nations, regulators, stakeholders, and remediation contractors) come together with problem solvers (such as scientists and engineers from the national laboratories and universities) to define problems and establish a path to solution. Periodically, these discussions and agreements are documented in revisions of the project's S&T roadmap. The roadmap describes the S&T objectives; briefly describes the scope and outcomes of S&T; links these outcomes to core projects within the Integration Project; and provides schedule, budget, and priorities for S&T activities. During fiscal year 2000 (FY00), the S&T endeavor began implementation of the S&T roadmap.

1.1 OBJECTIVE OF S&T ENDEAVOR

The GW/VZ Integration Project was established by DOE to ensure protection of the Columbia River environment, including river-dependent life and users of river resources. The Integration Project now serves as the single entity accountable for the integrated management of vadose zone, groundwater, and Columbia River activities at the Hanford Site. This integrated management role involves five endeavors:

- Integrate characterization and assessment work affecting long-term risk assessments (Integration).
- Assess the potential long-term effects of Hanford Site contaminants (System Assessment Capability [SAC]).
- Enhance the role of science and technology in cleanup decisions (S&T).
- Ensure productive involvement by parties interested in affecting Hanford's cleanup (Public Involvement).
- Ensure independent technical reviews and management oversight of the Integration Project (Technical Review).

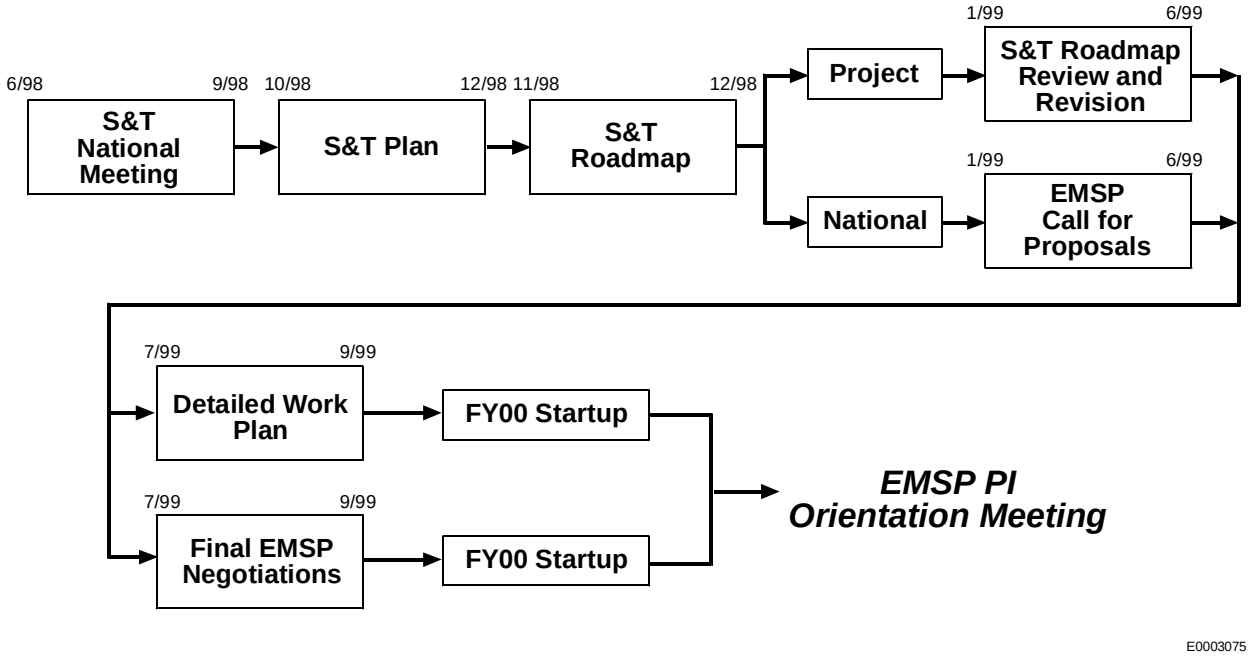
These are described in Volume I of the *Project Summary Description* document.

The objective of the S&T endeavor is to provide new knowledge, data, tools, and the understanding needed to enable the Integration Project's mission. S&T is focused on resolving key technical issues that help inform and influence decisions on remediation and closure of tank farms, and contaminated soil sites, in partnership with both the SAC and core projects (which are projects that are influenced by the Integration Project). This roadmap describes the S&T endeavor needed to meet this objective.

1.2 EVOLUTION OF THE ROADMAP

The S&T roadmap is a dynamic and evolving document. The evolution and implementation of the roadmap during FY99 is shown in Figure 1-1. The information presented here reflects the current state of Integration Project planning and implementation for Rev. 1 of this document. The process used to define FY00 S&T work scope within the Integration project will be repeated to define work scope for FY01 and future years.

Figure 1-1. Evolution of the S&T Roadmap During FY99.



As shown in Figure 1-1, the roadmap provided the basis for defining the FY00 S&T scope of work for the Integration Project and influenced a call for proposals by the DOE Environmental Management Science Program (EMSP). The scope of work and budgets for FY00 were prioritized in Rev. 0 of the roadmap to guide investments in the event that the full budget was not available. The Integration Project S&T needs were used to influence the FY99 EMSP call for proposals. Principal investigators from across the DOE complex, universities, and private industry responded to the call for proposals. These proposals were subjected to both technical and relevancy reviews and a certain number of them were funded. During November 1999, the Integration Project led an orientation workshop for the successful EMSP investigators to link their efforts with the Hanford Site S&T endeavor and the SAC and core projects. These EMSP projects have been identified in the current version of the roadmap where they have the opportunity to contribute S&T outcomes to the Integration Project and core projects, and are listed in Section 2.0.

This version of the roadmap provides an update to Rev. 0 of the roadmap and the draft S&T plan. The roadmap has been revised to include the risk technical element and incorporate the EMSP projects that were awarded in FY99. The S&T outcomes were revised to match changes in SAC and core project strategies and schedules. As with the previous draft, the S&T outcomes are linked to key decisions facing the Hanford Site, and to the projects executing work to address these decisions for the compliance case (i.e., to meet the current *Hanford Federal Facility Agreement and Consent Order* [*Tri-Party Agreement*]).

1.3 APPROACH FOR REVISING THE ROADMAP

The S&T program is organized along technical lines that are referred to as technical elements. The inventory, vadose zone, groundwater, and Columbia River technical elements provide the technical information and data to characterize various features and key processes essential to development of conceptual and numerical models that attempt to describe how the natural system works. The risk assessment and monitoring technical elements identify the methods and capabilities required for performing and evaluating site-wide system assessments. The remediation element identifies potential improvements to the Hanford Site's cleanup strategy.

This version of the S&T roadmap reflects updates of S&T scope and outcome, based on continuing discussions with the core projects. The System Assessment Capability, 200 Area Remedial Action Project, and the River Protection Project (RPP) Vadose Zone Project have updated their planning schedules. The S&T outcomes in this version of the roadmap have been updated to match the current project schedules. The roadmap continues to include priorities established for S&T outcomes (rather than the more general category of S&T activities). The FY00 budgets presented in this revision reflect the *Detailed Work Plan* that was developed during the summer of 1999. The out-year budgets are projections based on envisioned scope.

To develop Rev. 0 of the S&T roadmap, a series of national laboratory meetings were held in FY98. In these meetings, scientific experts in subsurface assessment and remediation met with the DOE, site remediation contractors, and local stakeholders. Many of these scientists had developed assessment capabilities for other DOE programs (such as Yucca Mountain). This diverse set of experience and capability was used to identify the scientific and technical challenges facing the Hanford Site, and to subsequently define S&T activities and outcomes to address these challenges.

Rev. 1 of the S&T roadmap adds the risk assessment technical element to the inventory, vadose zone, groundwater, and Columbia River elements. The risk assessment technical element was developed through meetings during FY99 and FY00 with representatives of the DOE Center for Risk Excellence, universities, DOE national laboratories, regulators, Native American Tribes, and stakeholders. In FY01 and 2002, the remediation and monitoring technical elements will be added to the roadmap. For information purposes, the current S&T activities identified for the remediation technical element are included in Appendix A. The remediation needs were

identified through the Hanford Site Technology Coordination Group (STCG)[1] with support from the Mixed Waste, Tanks, and Subsurface Contaminants subcommittees. These needs are currently executed through the core projects, rather than through the S&T activities and outcomes described in this roadmap.

1.4 SUMMARY OF S&T NEEDS AND S&T ACTIVITIES

This section presents a brief summary of the needs associated with the inventory, vadose zone, groundwater, Columbia River, and risk technical elements, and the proposed S&T activities to address those needs. A more detailed description of these needs from the national laboratory meetings and other site needs identified through the STCG can be found in Appendix B. A more detailed description of each of the S&T activities (and the outcomes and links to the SAC and individual projects) is presented in Sections 2.0 and 3.0.

1.4.1 Inventory Technical Element

Need: An approach is needed to provide a mass balance-based inventory of contaminants in soil sites that can be used by the SAC and individual projects. The inventory element builds on existing information about the amount and nature of the Hanford Site inventory that already exists in different forms. Several systems (Tank Waste Information Network System, Waste Information Data System, and Solid Waste Information Tracking System) are available at the Hanford Site that track inventories. Based on past assessments at the Hanford Site, four problems have been identified: 1) there are a large number of sites and contaminants; 2) inventory data that meet data quality requirements are not available for all of the sites and contaminants; 3) characterization to obtain these missing inventory data is expensive and time consuming; and 4) current approaches for inventory estimates introduce large uncertainty in a system assessment.

Solution: To respond to this need, the S&T endeavor will develop the understanding and models that describe the estimates and uncertainty for:

- Partitioning of wastes in process streams that were discharged to soils
- Behavior of specific contaminants for which reconciliation of inventory is important, but has not been achieved in past efforts
- Release mechanisms and rates from the source term to the soils.

[1] The STCG is a group of users and stakeholders at the Hanford Site. This group identifies technology needs that are annually submitted to the Office of Science and Technology (OST). OST, through its national research programs, considers these needs in the development of their technology programs. The science and technology needs are documented in *Hanford Science and Technology Needs Statements*, DOE/RL-98-01, Draft, U.S. Department of Energy, Richland Operations Office, Richland, Washington. These needs can also be accessed through http://www.hanford.gov.

In addition, S&T activities will be focused on reconciliation of model and field data (as needed) to reduce uncertainty in inventory estimates.

1.4.2 Vadose Zone Technical Element

Need: The flux of contaminants through the vadose zone to the groundwater under varying geologic, hydrologic, and chemical conditions is key to making technically credible and sound decisions regarding soil site characterization and remediation (e.g., for carbon tetrachloride), single-shell tank (SST) retrieval (where operational or tank leaks may occur), and tank and/or waste site farm closures. Past knowledge has not always been sufficient to forecast the quantity, location, and movement of contaminants under the varied conditions that exist in the vadose zone at the Hanford Site. Because of environmental, safety, and health considerations associated with subsurface contamination and the unconsolidated and heterogeneous geology at the Hanford Site, the cost for characterization has been high, and characterization tools have not been available for collecting some types of field data. Hence, there is a need to improve the conceptual and numerical models that describe the location of contaminants today, and to provide the basis for forecasting future movement of contaminants on both site-specific and site-wide scales. These forecasts provide the basis for planning site characterization efforts. There is also a need for advanced characterization and monitoring tools to improve detection and monitoring of non-gamma-emitting contaminants of concern in the vadose zone.

Solution: To respond to this need, the S&T endeavor will develop field and laboratory studies that:

- Result in improved conceptual and numerical models of important aspects of contaminant behavior in the vadose zone
- Include evaluations of water and contaminant movement at representative, contaminated, and uncontaminated field sites and targeted investigations to define controlling physical and chemical processes
- Provide focused laboratory experiments on waste-sediment interactions and chemical transport; and development of improved (multiphase reactive) transport models to forecast future migration of contaminants and influence remedial actions
- Provide opportunities to deploy and test advanced characterization tools and methodologies, to clearly identify mechanisms and processes that control the depth and extent of contaminant plumes in the Hanford Site vadose zone, and to calibrate and refine predictive transport models.

The planned activities of the vadose zone element will be coordinated with ongoing field characterization efforts at tank farms and soil waste sites to provide direct S&T input.

1.4.3 Groundwater Technical Element

Need: Although the understanding of the groundwater technical element is somewhat more mature than the understanding of other technical elements, there are still some areas where S&T is needed--particularly as site-wide system assessments are conducted. For example, the three-dimensional (3D) plume distributions in the groundwater, at the interface within the vadose zone, and at the interface between the groundwater and river are not well known. Moreover, characterization, 3D modeling, and parameter estimation across a hierarchy of spatial scales will be needed for some site-specific assessments (as well as site-wide assessments). Finally, groundwater in the 200 Area has potential dense non-aqueous phase liquid (DNAPL) contamination and transuranic (TRU) wastes (such as plutonium, cesium, and neptunium). This combination of contaminants can be both an assessment and a remediation challenge.

Solution: To address this need, the S&T endeavor will develop studies that provide:

- Depth-discrete sampling at key locations to investigate GW/VZ interactions
- Biogeochemical reactive transport studies to address reduction oxidation (redox) conditions, evaluate the impacts of complexants, and study the nature and location of DNAPL
- Scientific and technical input for improved mapping of hydrogeological controls on contaminant transport. This effort should focus on understanding and characterizing heterogeneity and quantifying uncertainty
- Field-scale evaluation of the regional 3D geometry of contaminant plumes
- Multi-scale 3D modeling based on objectives to be determined in concert with SAC requirements and individual project needs
- Groundwater-river discharge studies to determine the location of contaminant releases and the estimation of contaminant flux to the Columbia River.

1.4.4 Columbia River Technical Element

Need: Potential impacts and consequences of contaminant migration from the Hanford Site may be manifested in the Columbia River. To conduct the site-wide system assessment of the potential impacts of alternative remedial actions on the Columbia River, an enhanced understanding of the river environment is needed. The assessment of the river needs to account for multiple contaminant inputs from sources; the transport and fate of those contaminants in the river environment (physical, chemical, and biological systems); and the potential impacts of those contaminants.

Solution: To address this need, the S&T endeavor will develop:

- Enhanced conceptual models of the river, using new information and existing monitoring data from multiple agencies
- Methods and data for characterizing the river and describing transfer factors and input parameters for transport and fate models
- Enhanced understanding of the potential impacts of groundwater discharge to the river on affected biota, as well as confirming transport and fate predictions in the river.

1.4.5 Risk Technical Element

Need: During development of the Columbia River Comprehensive Impact Assessment, stakeholders, Tribal Nations, and regulators requested that future assessments of the Hanford Site and the Columbia River address many questions not included in standard risk assessments (DOE-RL 1998). In addition, these participants supported development of information to reduce the uncertainty in current risk assessment methodologies. The breadth of risks identified includes ecological, human health, economic, and socio-cultural impacts. Consideration of these risks in decision making is becoming important nationally, e.g., economic risks have been included in recent guidance from the U.S. Environmental Protection Agency (EPA) Science Advisory Board, human health effects from mixtures is in current calls for proposals in the EPA National Center for Environmental Research, and socio-cultural risks were included in a recent report by the DOE Center for Risk Excellence.

Solution: To address this need, the S&T endeavor will develop studies that:

- Provide data to reduce uncertainty in ecological risk assessment through more accurate and precise assessments of the probability of some adverse effect to ecological resources
- Provide data to facilitate scientifically defensible, realistic, credible, and comprehensive risks to humans from environmental exposures
- Develop methods for economic impact assessments based on realistic trigger mechanisms, regional economic activities, and estimation of economic benefit associated with specific natural resources
- Result in conceptual models for inclusion of socio-cultural impacts in cumulative risk assessments.

1.4.6 Remediation and Monitoring Technical Elements

The specific needs and recommended solutions for the remediation and monitoring technical elements will be developed through the roadmapping process similar to the other technical elements.

Need: The roadmap for the remediation and monitoring technical elements will be developed during FY01 and FY02. Some of the contamination problems that exist at the Hanford Site currently do not have cost-effective final remedial solutions. Improved remediation technologies and strategies are needed for long-lived radionuclide and chemical contaminants that exist in the vadose zone and groundwater at the Hanford Site. The DOE OST (DOE EM-50) has invested in remediation technologies that are applicable to the Hanford Site. Some of these technologies (e.g., surface barriers, in situ redox manipulation, in situ gaseous reduction) are in various stages of demonstration and deployment at the Hanford Site through DOE EM-40 and EM-50 programs.

Environmental monitoring will be deployed long after Hanford Site closure. Cost-effective long-term monitoring technologies and strategies are needed for Hanford Site contaminants in air, soil, the vadose zone, groundwater, the Columbia River, and biota.

Solution: To address this need, the S&T endeavor will:

- Identify, develop, and deploy improved vadose zone and groundwater remediation technologies and strategies

- Identify, develop, and deploy improved environmental monitoring technologies and strategies.

2.0 IMPLEMENTATION OF THE S&T ROADMAP

Two types of research are funded for the S&T endeavor. The first consists of shorter term applied research supported through Integration Project funding that contributes to specific Integration Project and core project milestones. The second consists of longer term (3 years) fundamental studies supported by the DOE EMSP Program through the FY99 call for proposals. Other activities funded by DOE EM-50, Office of Science and Technology, contribute to the S&T endeavor.

2.1 SITE-DIRECTED S&T

As described in Section 1.0, the Integration Project began implementing the S&T roadmap in FY00, with a few key activities in inventory and vadose zone beginning in FY99. The tasks being performed include activities to:

- Revise the S&T roadmap to include the Risk Technical Element.
- Interface with EMSP, core projects, SAC and Characterization of Systems tasks.
- Provide mass-balanced soil waste inventory to SAC, Rev. 0.
- Develop improved subsurface conceptual models of geochemical, hydrologic, and hydrochemical conditions and processes for Waste Management Area (WMA) S-SX.
- Conduct multiphase reactive transport modeling to support process-level conceptual model development.
- Define the strategy and test plan, complete field design, and conduct a vadose zone transport field study.
- Select and apply advanced characterization technologies to the vadose zone transport field study and evaluate their applicability to characterization and monitoring at the Hanford Site.
- Refine the conceptual model of the zone of groundwater/river interaction for input to SAC, Rev. 1.

2.2 S&T LINKAGES WITH EMSP

The draft S&T plan and the S&T roadmap for the Integration Project were used as input to the FY99 EMSP call for proposals. As a result, many of these EMSP projects have objectives and scope that are aligned with the technical elements funded by the Integration Project. A number of activities have been defined to enable these scientific research projects to be relevant to the

scientific and technical challenges facing the Hanford Site. The goal is to maximize the usefulness of the EMSP research to accomplish Integration Project and core project objectives. The DOE OST directs the research conducted through the EMSP projects, so the EMSP principal investigators are being voluntarily involved in the S&T conducted for the Integration Project. Three activities will help accomplish this involvement:

- To increase awareness of EMSP investigators of the scientific questions faced by the Hanford Site, an orientation meeting was conducted during November 1999 and annual technical exchanges are planned.

- The Integration Project has provided the EMSP investigators with guidance and information to enhance the relevance of their planned research to Hanford Site issues and to solicit their involvement in resolution of key scientific issues that fall within the scope of their projects.

- The Integration Project is providing Hanford Site materials (e.g., sediment and water samples) for performing EMSP experiments and involving EMSP investigators, on a voluntary basis, on performance of Integration Project S&T research, specifically field experiments that will be conducted.

During FY01 through 2003, funding provided by DOE EM-50 will be used to link the EMSP projects to the Integration Project S&T endeavor. A series of activities are planned to accomplish this goal, including the following:

- EMSP principal investigator meeting in FY00 and a coordination meeting in FY01 to facilitate planning, including sample allocation and site access

- Project interfaces to provide EMSP principal investigators with information and materials to ensure their research is relevant to Hanford Site conditions

- Technical exchanges to provide opportunities for in-depth technical discussions between EMSP investigators and project scientists and engineers on scientific issues associated with the Integration Project

- Data and knowledge transfer to ensure that results from the EMSP projects have a mechanism to provide specific data and knowledge to the Integration Project.

The contributions of these EMSP projects to the S&T and core project outcomes will be defined through interactions between the scientists and users and documented in implementation plans for the individual S&T elements. A significant portion of the S&T outcomes defined in the roadmap will be accomplished through the EMSP projects awarded during FY99. For the field investigations of representative sites, transport field studies, and transport modeling elements, most of the EMSP projects are focused on longer term, fundamental science issues with results expected in the 2- to 3-year time frame. These contributions will be balanced with investments made by the Integration Project focused on shorter term science issues with results expected in approximately a 1-year time frame and linked directly to site milestones. For the vadose zone

transport field study element, the EMSP projects are linked directly into field experiments that will be performed and evaluations of advanced characterization technologies, with results expected in the 1- to 3-year time frame.

As described, the first step in engaging the EMSP principal investigators in Integration Project activities was the November 1999 orientation meeting. During this meeting, presentation sessions were conducted to provide opportunities for the EMSP principal investigators to present their research plans, as well as for the Integration Project and core project scientists to present their plans and science needs. Through open discussion, the EMSP projects were aligned with Integration Project S&T technical elements, and where appropriate, core projects. The EMSP projects from the FY99 awards are listed in Table 2-1, along with a brief description of their scope.

During FY00, the Integration Project has funded an activity to identify and evaluate the applicability of other relevant EMSP and DOE-EM-50 work through the Subcon Focus Area (SCFA) to the Integration Project's activities. Principal investigators working on relevant EMSP and SCFA projects funded prior to the FY99 call will be included in future technical exchanges and their research will be incorporated into future revisions of the S&T roadmap.

2.3 S&T LINKAGES WITH DOE EM-40 AND EM-50

During FY00, technology development activities outside of the S&T endeavor are being conducted at the Hanford Site. Many of these activities are intended to improve the technical basis and reduce the costs of waste management, environmental protection, and site restoration.

Surface barrier monitoring and testing continues at the Hanford Site. A 4-year treatability test, which began in 1994, was successfully completed in 1998 for the Hanford Prototype Barrier Project. The project was designed to evaluate and document surface barrier constructability, construction costs, and physical and hydrologic performance over the 216-B-57 Crib in the 200 East Area. Treatability tests were conducted in two phases: Phase I included the design and construction of the prototype and was completed in 1994, and Phase II included the 4-year testing and monitoring effort. The function of the surface barrier is to ensure buried wastes are contained and protected from the infiltration of water, surface erosion, and bio intrusion. Testing was completed for water balance within the barrier under conditions of ambient and extreme precipitation, surface wind and water erosion, stability of the barrier foundation, surface and rip-rap side slope, surface vegetation dynamics, and animal intrusion. During the treatability testing period, results demonstrated the ease of construction with standard construction equipment, all design performance criteria were met or exceeded, and the design components were highly effective (DOE-RL 1999). Measuring and testing of the surface barrier continued into FY00 at a reduced level to collect longer term data.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
Waste/Sediment Lab Experiments and Process Models			
70070	Dr. Kathryn L. Nagy, University of Colorado	Reactivity of Primary Soil Minerals and Secondary Precipitates Beneath Leaking Hanford Waste Tanks	This research will investigate mineral reaction kinetics and the dynamic interaction with flow fields and waste tank contaminant sorption. Gaining fundamental knowledge on the minerals that will be dissolved, the minerals that will be precipitated, and the dynamic interaction of these processes with the flow and contaminant sorption will allow scientifically defensible decisions on tank remediation to be made.
70081	Dr. Samuel J. Traina, Ohio State University	Immobilization of Radionuclides in the Hanford Vadose Zone by Incorporation in Solid Phases	This research addresses how, and under what conditions, soluble Cs, Co, Sr, Tc, and U in single-shell tank leachates are attenuated in the vadose zone through adsorption and precipitation reactions. This information will have direct impact on the development of geochemical transport models and on remediation strategies that deal with vadose zone contaminants in high-level waste tank plume environments.
70121	Dr. John M. Zachara, Pacific Northwest National Laboratory	The influence of Calcium Carbonate Grain Coatings on Contaminant Reactivity in Vadose Zone Sediments	This research project will investigate the role of calcium carbonate grain coatings on vadose zone chemical reactivity. Carbonate grain coatings may be a critical determinant of the long-term behavior of important DOE contaminants, especially at western sites where calcareous sediments are common.
70126	Dr. Jonathan Chorover, Pennsylvania State University	Collaboration: Interfacial Soil Chemistry of Radionuclides in the Unsaturated Zone	The purpose of this research is to quantify the rate and extent of radionuclide sorption/desorption on pristine and altered clay surfaces and layered silicates through macroscopic batch and column experiments. The results obtained will find application in equilibrium and transport models for quantifying radionuclide distribution among solid, colloidal, and dissolved phases. Such models are already in use for predicting future migration of contaminant plumes.
70135	Dr. Markus Flury, Washington State University	Colloid-facilitated Transport of Radionuclides Through the Vadose Zone	This research will study three major processes responsible for colloid-facilitated transport: formation and mobilization of colloids, association of contaminants with colloidal particles, and co-transport of colloids and contaminants in the vadose zone. The results of this research will lead to improved conceptual models of colloid-facilitated transport at the Hanford Site.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
70146	Dr. Richard J. Reeder, State University of New York at Stony Brook	Spectroscopic and Microscopic Characterization of Contaminant Uptake and Retention by Carbonates in Soils and Vadose Zone Sediments	The purpose of this research is to characterize the uptake and retention of key metal contaminants (Co, Cs, Pb, Sr, Cr, and U) on calcium carbonate (calcite). The results of this research will provide direct validation of process models and facilitate better understanding of mechanisms by which key metal contaminants are retained/released in soils.
70163	Dr. Andrew R. Felmy, Pacific Northwest National Laboratory	The Aqueous Thermodynamics and Complexation Reactions of Anionic Silica Species to High Concentration: Effects on Neutralization of Leaked Tank Wastes and Migration of Radionuclides in the Subsurface	This research will determine the aqueous thermodynamics and speciation of dissolved silica and silica-radionuclide complexes to high silica concentration. Results will help DOE to answer key questions of how leaking solutions from single-shell tanks at the Hanford Site are modified by interactions with the subsurface and how the radionuclides are transported in the subsurface/vadose zone.
70176	Professor Heino Nitsche, Lawrence Berkeley National Laboratory	Transuranic Interfacial Reaction Studies on Manganese Oxide Hydroxide Mineral Surfaces	This research will provide additional information on the interfacial reactions of neptunium and plutonium with manganese oxide and hydroxide mineral surfaces relevant to contaminant transport in the vadose zone. Surface complexation models will be developed to provide prerequisite information for reactive transport modeling that will lead to an improved basis for predicting transuranic migration in the vadose zone to nearby water supplies.
70177	Dr. Nancy J. Hess, Pacific Northwest National Laboratory	Technetium Attenuation in the Vadose Zone: Role of Mineral Interactions	This research will determine the mechanisms of surface-mediated reduction/precipitation reactions of Tc on Fe^{II}-containing mineral surfaces and the composition of these precipitates, and build a thermodynamic database for the solubility-limiting phases and aqueous species.
		Vadose Zone Transport Field Studies	
70069	Dr. Tetsu K. Tokunaga, Lawrence Berkeley National Laboratory	Fast Flow in Unsaturated Coarse Sediments	This research will improve our understanding of unsaturated flow in coarse- to very coarse-textured sediments. Through development of new conceptual models and laboratory experiments on fast flow processes, results will help to predict contaminant transport in vadose environments.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
70108	Dr. Patricia A. Berge, Lawrence Livermore National Laboratory	Effects of Fluid Distribution on Measured Geophysical Properties for Partially Saturated, Shallow Subsurface Conditions	The objective of this work is to develop relationships between laboratory measured geophysical properties and porosity, saturation, and fluid distribution for partially saturated soils. Results will improve interpretation of geophysical data collected in the field for characterizing in situ soils in the subsurface and fill materials such as sands used in capillary barriers.
70149	Dr. Charles R. Carrigan, Lawrence Livermore National Laboratory	The Dynamics of Vadose Zone Transport: A Field and Modeling Study Using the Vadose Zone Observatory	This research program will characterize vadose zone fluid flow and contaminant transport processes for the purpose of making improved estimates of contaminant release rates and fluxes across the vadose zone to the water table at DOE sites.
70193	Dr. Christopher J. Murray, Pacific Northwest National Laboratory	Influence of Clastic Dikes on Vertical Migration of Contaminants in the Vadose Zone at Hanford	This research will investigate the possibility that clastic dikes at the Hanford Site provide preferential pathways that enhance the vertical movement of moisture and contaminants through the vadose zone. The new characterization techniques to be demonstrated in the project could be applied at other contaminated vadose zones at the Hanford Site, as well as at other sites where vertical faults influence the contaminant transport through sediments.
70219	Dr. Philip M. Jardine, Oak Ridge National Laboratory	Fate and Transport of Radionuclides Beneath the Hanford Tank-Farms: Unraveling Coupled Geochemical and Hydrological Processes in the Vadose Zone	This research will provide an understanding and predictive capability of coupled hydrological and geochemical mechanisms that may be responsible for the enhanced migration of radionuclides in the vadose zone at the Hanford Site. Unsaturated flow and transport experiments, combined with multiple tracer strategies and novel surface analyses, will provide knowledge in previously unexplored areas of vadose zone contaminant transport.
Transport Modeling			
70187	Dr. Philip D. Meyer, Pacific Northwest National Laboratory	Quantifying Vadose Zone Flow and Transport Uncertainties Using a Unified, Hierarchical Approach	This research project will develop and demonstrate a general approach for modeling flow and transport in a heterogeneous vadose zone using geostatistical analysis, media scaling, and conditional simulation to estimate soil hydraulic parameters at unsampled locations from field-measured water content data and a set of scale-mean hydraulic parameters. The research results will help to elucidate relationships between the quantity and spatial extent of this characterization data and the accuracy and uncertainty of flow and transport predictions.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
Advanced Vadose Zone Characterization			
70010	Dr. William R. Heineman, University of Cincinnati	Spectroelectrolchemical Sensor for Technetium Applicable to the Vadose Zone	This research will develop a technetium (Tc) sensor capable of characterizing and monitoring the vadose zone and subsurface water contamination at the Hanford Site. The sensor will determine the concentration of Tc in various chemical forms by combining three modes of selectivity: electrochemistry, spectroscopy, and selective partitioning.
70052	Dr. John Bradford, University of Wyoming	Material Property Estimation for Direct Detection of DNAPL using Integrated Ground-Penetrating Radar Velocity, Imaging, and Attribute Analysis	This research will develop a suite of methodologies for direct detection of pooled and residual DNAPLs from surface ground-penetrating radar (GPR) data. This unique approach to the analysis of GPR data will determine material properties remotely by quantifying signal characteristics such as propagation velocity and waver form attributes such as amplitude, frequency content, and phase. This effort, if successful, will reduce the cost of DNAPL remediation.
70115	Dr. Rosemary Knight, University of British Columbia	The Use of Radar Methods to Determine Moisture Content in the Vadose Zone	This research will focus on two specific aspects of the link between radar images ad moisture content, which is a critical parameter affecting both liquid-phase and vapor-phase contaminant transport in the vadose zone. The research will improve the usefulness of radar methods (ground-based and borehole) as a means of characterizing moisture content in the vadose zone.
70220	Dr. Gregory A. Newman, Sandia National Laboratories	High Frequency Electromagnetic Impedance Imaging for Vadose Zone and Groundwater Characterization	This research will address the use of magnetotelluric (MT) inversion codes to interpret data and limiting factors of 2D and 3D inversion schemes. Results will help DOE develop better ways to characterize the subsurface and thereby predict contaminant transport in the vadose zone.
70267	Dr. David Alumbaugh, University of Wisconsin at Madison	A Hydrologic-Geophysical Method for Characterizing Flow and Transport Processes within the Vadose Zone	This research will analyze flow within a mid-scale hydrologic test to determine the amount of transport within the vadose zone. This project will employ numerical and experimental tools being developed under previously funded EMSP research. Results will help to better understand flow and transport modes within the vadose zone at DOE sites, including the influence of natural heterogeneities and man-made structures.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
Biogeochemical Reactive Transport			
70063	Dr. Perry L. McCarty, Stanford University	Biodegradation of Chlorinated Solvents" Reactions Near DNAPL and Enzyme Functions	This research will study processes affecting in situ biodegradation of DNAPLs and their degradation daughter products. These biological processes are inadequately understood at present, and this research is essential both for evaluating the true potential for bioremediation at some sites and for reliable engineering of the process at others.
Monitoring			
70012	Dr. Stephen R. Brown, New England Research, Inc.	Complex Electrical Resistivity for Monitoring DNAPL Contamination	This research will develop a new methodology for field measurement of complex resistivity for characterization and monitoring of DNAPLs. The resistivity measurements will be an effective tool for monitoring the progress of remediation activities.
70050	Dr. S. Michael Angel, University of South Carolina	Novel Optical Detection Schemes for In situ Mapping of Volatile Organochlorides in the Vadose Zone	This research will study the resonance-enhanced multi-photon ionization (REMPI) method for measuring organic solvents in a soil matrix by detecting organic vapors in the vicinity of a nonaqueous phase liquid. REMPI and Raman spectroscopy will be used together to allow measurement and identification of organic contaminants over a wide range of concentrations. Use of visible lasers for excitation could further reduce instrumentation cost and complexity.
70179	Dr. Jay W. Grate, Pacific Northwest National Laboratory	Radionuclide Sensors for Water Monitoring	This research program will develop sensor concepts and materials for sensitive and selective determination of beta- and alpha-emitting radionuclide contaminants in water. Results will provide knowledge to enable development of highly accurate in situ sensors. With such sensors it will be possible to make high-speed, accurate, high-resolution analyses of different contaminant species in situ.
Remediation			
70035	Dr. Susan E. Powers, Clarkson University	DNAPL Surface Chemistry: Its Impact on DNAPL Distribution in the Vadose Zone and its Manipulation to Enhance Remediation	The goal of this research is to understand the role in interfacial phenomena on the accessibility of DNAPLs in the vadose zone. This effort could potentially be used to increase the recovery of DNAPLs during vapor extraction and other vadose zone remediation efforts.

Table 2-1. FY99 EMSP Awards. (6 Pages)

Project Number	Lead PI and Organization	Title	Summary
70045	Dr. Albert Valocchi, University of Illinois at Urbana-Champaign	Investigation of Pore-Scale Processes Which Affect Soil Vapor Extraction	This research will determine the pore-scale processes that limit the removal of DNAPL components in heterogeneous porous media during soil vapor extraction (SVE). Magnetic resonance imaging (MRI) will be used to observe and quantify the location and amount of DNAPLs in individual pores. A site-scale transport model will be developed to evaluate how the different processes affect SVE performance in practical applications.
70088	Dr. Baolin Deng, New Mexico Institute of Mining & Technology	Interfacial Reduction-Oxidation Mechanisms Governing Fate and Transport of Contaminants in the Vadose Zone	The purpose of this research is to determine the kinetics and mechanism of interaction among hydrogen sulfide, metal contaminants, and soil components. A mechanistic understanding of the interfacial redox transformation will be developed in collaboration with spectroscopic studies, and a model incorporating reaction kinetics and H_2S gas flow will be developed to design an improved in situ gas-reduction system.
70132	Dr. Ken O. Buesseler, Woods Hole Oceanographic Institute	Speciation, Mobility and Fate of Actinides in the Groundwater at the Hanford Site	The purpose of this research is to provide the basis for accurate modeling and prediction of actinide transport, thus allowing remediation strategies to use in situ manipulations of geochemical variables to enhance extraction or to retard immobilization in groundwater.
70165	Dr. Fred J. Brockman, Pacific Northwest National Laboratory	Integrated Field, Laboratory, and Modeling Studies to Determine the Effects of Linked Microbial and Physical Spatial Heterogeneity on Engineered Vadose Zone Bioremendation	This research will evaluate an approach for removal of carbon tetrachloride from the vadose zone using enhanced biodegration via gas-phase nutrient injection. Results will be used to improve the accuracy of current models that predict microbial attenuation of contaminant transport in the vadose zone.
70206	Dr. Robert W. Smith, Idaho National Engineering and Environmental Laboratory	Calcite Precipitation and Trace Metal Partitioning in Groundwater and the Vadose Zone: Remediation of Strontium-90 and Other Divalent Metals and Radionuclides in Arid Western Environments	This research intends to clarify the mechanisms and rates of microbially-facilitated calcite precipitation and divalent cation adsorption/co-precipitation occurring in a natural aquifer and vadose zone perched water body as a result of the introduction of urea. The effects of spatial variability in aquifer host rock and the associated hydro-biogeochemical processes on calcite precipitation rates and mineral phases within an aquifer will also be determined.

In response to a request by the DOE Office of River Protection, the DOE-EM TechCon and Innovative Treatment Remediation Demonstration (ITRD) programs [2] conducted a 2-day forum during May 1999 to seek assistance in reducing water infiltration around Hanford Site single-shell tanks. The purpose of the forum was to identify a range of commercially available alternatives and provide opportunity for interactions between site contractors, vendors, scientists, and stakeholders. Technical sessions were held on the following areas of interest: moisture characterization and monitoring, structures, surface covers, and near-surface barriers. Commercial vendors with experience in monitoring subsurface moisture and controlling surface-infiltration of water into radioactively contaminated soils participated in the forum. The team performed an analysis on the ability of the different alternatives presented to meet Hanford Site requirements. The conclusions and recommendations from the meeting were as follows:

- Significant commercial capabilities and relevant experience were available for each of the major areas of interest
- The technologies are available for deployment in less than 6 months following receipt of an order by the vendors
- Moisture monitoring capabilities are compatible with conditions that exist at the Hanford Site and monitoring could be considered for mitigating characterization uncertainty in the short term
- There is a strong bias for deployment, rather than demonstration; available technologies were considered to be adequate
- Time is of the essence in acting to minimize water infiltration and the information presented suggested significant cost and schedule savings associated with early action
- There is no single technology/solution to address all of the issues that exist; a combination of alternatives that were presented will be suitable for minimizing water infiltration under tank farm conditions
- Deployment of technologies should be done in a phased approach; the first application should be in a tank farm known to have contaminant migration.

In the 100-D Area, in situ redox manipulation is being implemented to remediate hexavalent chromium contamination in the groundwater. The redox barrier is expanding from a treatability test to implementation, and 14 wells are being installed to extend the length of the barrier, with 2 additional wells being installed for compliance monitoring. This is the first of three phases to complete the full extent of the redox barrier in this area.

[2] The TechCon Program is coordinated by Argonne National Laboratory with support from the Pacific Northwest National Laboratory. The ITRD Program is coordinated by Sandia National Laboratory. These programs cooperate in providing technical assistance to DOE site project teams that leverage environmental technologies for cost savings, schedule reduction, and risk management.

Through the DOE EM-50 SCFA, In Situ Gaseous Reduction is being demonstrated for remediation of the hexavalent chromium source term at the 183-DR site. This technology involves injection of dilute hydrogen sulfide into chromate-contaminated soil. The process chemically reduces Cr^{VI} to Cr^{III}, eliminating the toxicological risk of chromium.

The ITRD Program is funded by the DOE Office of Environmental Restoration (EM-40) to accelerate the implementation of new and innovative remediation technologies to assist DOE with solving environmental problems. The ITRD program attempts to reduce many of the classic barriers to use of new technologies by involving other government agencies, industry, regulatory agencies, stakeholders, and Tribal Nations in the assessment, implementation, and validation of innovative technologies. The ITRD Program initiated the Hanford 100-N Area Project in March 1998. The project addresses strontium-90 contaminated soil and groundwater in the 100-N Area. An advisory group composed of representatives from DOE, EPA, Washington State Department of Ecology, Tribal Nations, and stakeholders was established to assist with identifying, reviewing, and evaluating applicable innovative remediation technologies that target strontium-90 contamination in the vadose zone and groundwater. The goals of this project were to reduce contaminant concentrations in the Columbia River and restore the unconfined aquifer near the Columbia River. Constraints included potential impacts to the river, schedule, final land use, cultural issues, and programmatic risks. The criteria for evaluating potential technologies included cost, performance, and implementation criteria.

A total of 41 technologies that may have some potential for use at the 100-N Area were identified. These were screened to a list of eight technologies for further evaluation. Three of these technologies were focused on remediation of the source term and five were focused on reducing the flux of contaminants (primarily strontium-90) to the Columbia River. The advisory group identified data needs that are needed to support technology evaluations and testing and modeling studies were initiated to assist with determining the effectiveness of the technologies at the 100-N Area. These studies included groundwater flow and transport modeling, soil flushing, soil stabilization, and bank stability studies. Potential opportunities exist for the S&T endeavor to contribute to the ITRD project for the 100-N Area in data collection to assist with evaluation of remediation technologies.

The ITRD program is also conducting a project to develop a strategy for remediation of the carbon tetrachloride plume in the 200 West Area. A technology advisory group developed a project plan that includes the following activities:

- Initial review of potential remediation technologies (complete)
- Groundwater modeling of the carbon tetrachloride plume (in progress)
- Identification of carbon tetrachloride DNAPL in the vadose zone and groundwater
- Vadose zone modeling of the carbon tetrachloride plume
- Remediation alternative selection and recommendations for treatability studies
- Treatability studies
- Final recommendation for remediation.

The first task to review potential remediation technologies is complete. The technical advisory group identified and reviewed approximately 30 technologies they considered applicable to enhance remediation of the carbon tetrachloride contamination. Categories of technologies they considered included in situ treatment of contaminated groundwater, in situ treatment of contaminated low-permeability sediments, and in situ treatment of high-permeability sediments. Issues considered in evaluation of the technologies included: implementation costs and ease of implementation, technology maturity, life-cycle costs and overall cost-effectiveness, ability to reduce carbon tetrachloride to regulatory levels at the points of compliance, compatibility with existing site constraints and existing treatment systems, stakeholder considerations, and regulatory permitting issues. The general maturity and cost and performance characteristics were reviewed as they apply to the 200 West Area. Based on this information, the most promising technologies will be further assessed with engineering evaluations conducted in collaboration with several technology vendors.

The advisory group suggested additional modeling and characterization activities to assist in developing a final recommendation for implementation of a remediation strategy for the carbon tetrachloride plume. This forward path for the ITRD project provides opportunity for S&T contributions. EMSP projects 70012, 70035, 70050, 70052, and 70063 awarded in FY99 may contribute S&T results for the carbon tetrachloride problem. In addition, previous EMSP projects and those being considered for follow-on work may also contribute to the overall strategy for characterization and remediation of the carbon tetrachloride plume.

3.0 S&T LINKAGES TO SAC, CORE PROJECTS

This section of the S&T roadmap briefly describes the specific needs of each of the core projects within the Integration Project, and the linkages to S&T outcomes. The Integration Project components and core projects that receive products from S&T within the Integration Project include the following:

- SAC (Integration Project)
- Characterization of Systems (Integration Project)
- RPP Vadose Zone Project
- 200 Area Remedial Action Project
- River Monitoring Project
- Groundwater Project
- Immobilized Low-Activity Waste (ILAW).

The recently funded EMSP projects are also linked to the Integration Project through the S&T endeavor. A description of the EMSP projects and how they relate to the S&T endeavor has been provided in Section 2.0.

For the Integration Project to have an impact, it must deliver correct scientific and technical information in a timely manner that allows S&T outcomes to be used to meet the Integration Project and core project(s) objectives. Hence, the outcomes for S&T were defined based on the needs described in Section 1.3, and through ongoing discussions between the scientists and the projects. The schedules for delivering those key S&T outcomes were linked to schedules established by the SAC and core projects for planning purposes. The core project baselines and milestones may vary from these planning estimates, and S&T activities will be adjusted to reflect these changes. In particular, the target schedule for S&T (in Table 3-1) was used to identify S&T activities in advance of when the projects need the results. The key project dates are when the input from S&T will be provided to the SAC and core projects.

Linkages of the S&T endeavor to the core projects and SAC are occurring through science/user teams that have been defined for each active S&T technical element. The science-user teams involve Integration Project and core-project end users (e.g., from RPP and 200 Area Remedial Action projects, and SAC), National Laboratory experts in appropriate scientific disciplines (e.g., geochemistry, hydrology/soil physics, reactive transport modeling), and selected EMSP principal researchers whose projects closely relate to the objectives of the S&T activity. These teams are responsible for planning and implementing the work for each S&T technical element and ensuring the S&T results are relevant to addressing the user's needs.

Table 3-1. Schedules for the SAC and Core Projects.

Core Project	Project Activity	Key Dates for S&T Input
SAC	Data Gathering for Rev. 0	May 00
	Data Gathering for Rev. 1	Oct 01
	Data Gathering for Rev. 2	Apr 03
	Data Gathering for Rev. 3	Oct 04
RPP Vadose Zone Project	Field Investigation Report for S-SX Remedial Feasibility Study	Oct 00
	Field Investigation Report for B-BX-BY Remedial Feasibility Study	Jun 01
	Field Investigation Report for T-TX-TY Remedial Feasibility Study	Jul 02
	Phase 1 Remedial Facility Investigation Report	Oct 03
200 Area Remedial Action Project	Complete all 200 Area Soil Waste Site Assessment pre-Record of Decision site investigations	Dec 08

3.1 S&T LINKAGES TO THE SYSTEM ASSESSMENT CAPABILITY TASK

System Assessment Capability Task of the Integration Project: S&T activities linked to the SAC provide conceptual models, analytical and numerical models, data, and model parameters.

The SAC is a key tool being developed for use by the Integration Project. It provides a suite of models and parameter databases that can be used by the Integration Project to conduct site-wide system assessments. The results of these assessments will be used to make decisions regarding operations (e.g., land use) and remediation at the Hanford Site (e.g., tank retrieval, 100, 200, and 300 Area soil site cleanup). In FY99 and FY00, the SAC defined the requirements for analyses conducted at higher resolutions (space and time) on site-specific research scales. The SAC is working with the core project and S&T staff to define the effects of models developed and applied at differing scales, and the linkages between SAC technical elements.

The SAC is an important end user of S&T products. Within the next 5 years, the SAC will require input from the inventory, vadose zone, groundwater, Columbia River, and risk assessment technical elements in the S&T roadmap (as listed below). Some of the S&T outcomes impacting the SAC will also occur through linkages with the core projects that provide results to the SAC. (*Note*: A more complete description of the S&T outcomes, interfaces, and schedules can be found in Section 4.0, Table 4-1. The Identification Numbers [Id. No.] for each S&T outcome are listed in parentheses, below, to aid the reader in identifying the S&T outcomes [in Table 4-1] that provide input to the SAC.)

- Develop models that provide a mass balance accounting of contaminant quantity, volume, and timing of releases, with uncertainties, including estimates of containment failure and contaminant release for waste disposal in engineered or man-made systems (inventory technical element; Id. No. Inv-interim report, Inv-final reports, Inv-1 through Inv-23).

- Develop conceptual models, numerical models, and parameters for fate and transport through the vadose zone that allow flux predictions of contaminants from vadose zone sources to groundwater (vadose zone technical element; Id. No. VZ-interim report, VZ-final report 1, VZ-final report 2, VZ-5, VZ-6, VZ-11, VZ-12, and VZ-21 through VZ-23).

- Develop models and parameters for fate and transport of contaminants through the groundwater that allow flux predictions from groundwater to the river (groundwater technical element; Id. No. GW-1, GW-4 through GW-7, GW-9, GW-10, GW-13, GW-15, and GW-16).

- Define conceptual models of the groundwater/river interface and river; manage and utilize existing information from multiple agencies (as appropriate); adequately characterize the river environment to support impact evaluation and risk assessment activities; and define parameters required for determining the fate and transport of contaminants within and through the Columbia River (Columbia River technical element; Id. No. CR-1 through 21).

- Fill gaps for conducting ecological, human health, economic, and socio-cultural risk assessments (Risk technical element; Id. No. R-1 through R-27).

The SAC is currently replanning their iterative approach. Future revisions of the S&T roadmap will reflect the baseline changes that the SAC will develop.

3.2 S&T LINKAGES TO THE CHARACTERIZATION OF SYSTEMS TASK

Integration Project Characterization of Systems Task: S&T activities linked to the Characterization of Systems Task provide conceptual models and data to address issues raised to the Integration Project.

The Integration Project Characterization of Systems endeavor is responsible for developing and documenting conceptual models of the vadose zone, groundwater, and Columbia River; and populating and maintaining databases of consistent, peer-reviewed data. This endeavor is also responsible for documenting resolution of issues through the Features, Events, and Processes strategy. Much of the work being performed as part of the S&T endeavor and EMSP projects (FY99 and previous awards) will be used by the Integration Project to develop conceptual models, populate databases, and resolve technical issues. The specific linkages of the S&T outcomes to the Characterization of Systems endeavor as it becomes better defined.

3.3 S&T LINKAGES TO THE RPP VADOSE ZONE PROJECT

RPP Vadose Zone Project: S&T activities linked to the RPP Vadose Zone Project provide conceptual models, analytical and numerical models, data, and model parameters.

The RPP Vadose Zone Project is collecting field data to better assess the need for corrective measures that will mitigate further migration of contaminants released from tanks or ancillary facilities. The goal of the Tank Farm Vadose Zone Project is to provide data and understanding

on the impacts of tank waste that affect decisions regarding tank farm interim corrective actions, waste retrieval options, and closure alternatives. A key deliverable identified in Table 3-1 is the S&T input to the Remedial Feasibility Investigation report needed in September 2004 that describes the information, analyses, and recommendations related to the impacts of SST farm leaks. This report will be based on a combination of existing knowledge, results of new field characterization activities, analyses, and simulations of contaminant transport. The project will also take advantage information developed by others, including results of the 200 Area Remedial Action Project, the RPP Immobilized Waste Project, S&T outcomes, and other outcomes generated by the Integration Project. The S&T activities described in this roadmap generally support this core project's schedule for field investigations at the S-SX, B-BX-BY, T, and TX-TY WMAs. For each WMA, a field investigation report will be generated and will include relevant results from S&T outcomes. (*Note*: A more complete description of the S&T outcomes, interfaces, and schedules can be found in Section 4.0 [Table 4-1]. The Identification Numbers [Id. No.] for each S&T outcome are listed in parentheses below to aid the reader in identifying S&T outcomes [in Table 4-1] that provide input to the RPP.)

- Develop better models to estimate tank leak losses (inventory technical element; Id. No. Inv-1 through Inv-3; RPP lead).

- Conduct wrap-around science(*) at representative field sites to test alternative conceptual models to better understand the controlling contaminant migration processes near leaked tanks (vadose zone technical element; Id. No. VZ-1, VZ-3, and VZ-4) and to predict future migration resulting from recharge or tank retrieval losses with vadose zone transport modeling simulations (vadose zone technical element; Id. No. VZ-7, VZ-9, and VZ-10).

- As part of the wrap-around science effort, conduct laboratory studies to determine kinetic and thermodynamic data for key geochemical and hydrochemical reactions that control contaminant distribution and hydraulic flow in the vadose zone beneath boiling, concentrated, and dilute tank wastes sites (vadose zone technical element; Id. No. VZ-15, VZ-17 through VZ-19). EMSP projects 70070, 70081, 70121, 70126, 10135, 70146, 70163, 70176, and 70177 contribute to S&T outcomes associated with laboratory studies of vadose zone processes.

- As part of the wrap-around science effort, carry out vadose zone transport field studies at uncontaminated sites that allow reconciliation of conceptual models and facilitate validation/verification of transport models (vadose zone technical element; Id. No. VZ-21, VZ-22, and VZ-24). EMSP projects 70069, 70149, 70193, and 70219 contribute to S&T outcomes associated with vadose zone transport field studies.

- Test and evaluate advanced vadose zone characterization technologies and methods for measurement of water and solute transport at representative field sites, and at vadose zone transport field sites (vadose zone technical element; Id. No. VZ-25 through VZ-27). EMSP projects 70010, 70052, 70115, 70220, and 70267 may contribute S&T outcomes to advanced

(*) Wrap-around science refers to additional activities (such as sampling and analysis) that are pertinent to system assessment needs, and are conducted in conjunction with the site-specific project field activities that support scientific investigations beyond the project-specific objectives.

vadose zone characterization technologies. In addition, EMSP projects 70012, 70050, and 70179 may contribute to monitoring S&T outcomes and will be incorporated into the roadmap when the monitoring technical element is included.

- Reevaluate existing data from groundwater monitoring activities and conduct depth-discrete sampling in existing wells to collect additional data that describe the 3D plume in the groundwater near the near-source discharge from the vadose zone to past tank leaks (groundwater technical element; Id. No. GW-2 and GW-3).

3.4 S&T LINKAGES TO THE 200 AREA REMEDIAL ACTION PROJECT

200 Area Remedial Action Project: S&T activities linked to the 200 Area Remedial Action Project provide conceptual models, analytical and numerical models, data, and model parameters.

Characterization of the 200 Area waste site groupings was initiated in FY99. Analysis of field characterization results is required for completion of *Tri-Party Agreement* Major Milestone M-15-00C by December 2008. The *Tri-Party Agreement* milestone requires that 200 Area non-tank farm operable unit remedial investigations to support Records of Decision will be completed at that time. The S&T activities described in this roadmap support the 200 Area Remedial Action project through the following activities. (*Note*: A more complete description of the S&T outcomes, interfaces, and schedules can be found in Section 4.0 [Table 4-1]. The Id. No. for each S&T outcome is listed in parentheses below to aid the reader in identifying the S&T outcomes [in Table 4-1] that provide input to the 200 Area Waste Sites Assessment.)

- Develop inventory models to estimate the quantity, volume, and timing of releases to the soil sites receiving plant cooling water, chemical sewer, scavenging waste, and surface spills (inventory technical element; Id. No. Inv-4 through Inv-10).

- Provide conceptual models for contaminant transport at soil sites (vadose zone technical element; Id. No. VZ-final report 2,VZ-2, VZ-4, VZ-8, VZ-16, VZ-18, VZ-20, and VZ-22).

- Document the benefits of advanced vadose zone characterization tools (vadose zone technical element; Id. No. VZ-25 and VZ-26).

- Conduct laboratory studies on sites receiving TRU and organic wastes (e.g., DNAPLs), such as those received by the Z-9 Trench to investigate the extent of residual saturation, irreversible sorption and DNAPL (vadose zone technical element; Id. No. VZ-2 and VZ-16) and biogeochemical reactions (groundwater technical element; Id. No. GW-5 through GW-7). The DNAPL components are linked with the ITRD process for the carbon tetrachloride contamination in the 200 West Area. EMSP projects 70063, 70012, 70050, 70035, 70045, and 70165 may contribute S&T outcomes and will be incorporated into specific S&T activities when the remediation and monitoring technical elements are added to the roadmap.

- Conduct biogeochemical studies for TRU wastes at injection well sites (e.g., B-5 reverse well) (groundwater technical element; Id. No. GW-5 and GW-6).

- Reevaluate existing data from groundwater monitoring activities and conduct depth-discrete sampling in existing wells to collect additional data that describe the 3D plumes in the groundwater near vadose zone discharge locations (groundwater technical element; Id. No. GW-1).

3.5 S&T LINKAGES TO THE RIVER MONITORING PROJECT

River Monitoring Project: S&T activities will be integrated with the River Monitoring Project to ensure data and models can be used to determine monitoring requirements in the river to provide consistent input to the SAC for use in the Columbia River technical element.

The River Monitoring Project samples the Columbia River and the related environment to meet regulatory drivers. Results of river monitoring activities are used to determine compliance with applicable environmental standards, and to evaluate the current impacts of Hanford Site operations on the river. Because the Columbia River is a key technical element within the SAC to evaluate potential impacts and consequences of migrating contaminants, as well as the assessment of potential risk, S&T activities will be coordinated with the River Monitoring Project to obtain the needed data, parameters, and models. The following S&T activities have been identified for coordination with the River Monitoring Project. (*Note*: A more complete description of the S&T outcomes, interfaces, and schedules can be found in Section 4.0 [Table 4-1]. The Id. No. for each S&T outcome is listed in parentheses below to aid the reader in identifying the S&T outcomes [in Table 4-1] that provide input to the River Monitoring Project.)

- Develop a detailed conceptual model of the Columbia River system that includes the critical processes and components necessary to conduct a river assessment. This activity will also identify the links between activities across the technical elements and provide a basis for prioritizing and coordinating related activities, enabling S&T development and application for the river technical element in a meaningful manner. The current river conceptual model will be expanded to meet SAC requirements; identify existing data strengths and weaknesses; and define contaminant transfer factor requirements/needs (Columbia River technical element; Id. No. CR-1 through CR-3).

- Develop a functional information management system/process necessary to enable a river assessment, along with initiation of S&T development and application. This activity will identify, evaluate, and consolidate appropriate information from multiple agencies to support the expanded conceptual model (Columbia River technical element; Id. No. CR-4 through CR-7).

- Define the hydrologic setting, current contaminant levels, species abundance and diversity, sensitive habitats, and critical locations in the Columbia River environment, including the groundwater/river interface. In addition, define and verify input parameters, and provide

data for the verification/validation of fate and transport models to be used in the river assessment (Columbia River technical element; Id. No. CR-8 through CR-11).

- Develop data and models of the groundwater/river interactions, linking spatial scales of the groundwater model outputs with the scale necessary for ecological assessments and assessing the contaminant flux into the river (groundwater and Columbia River technical elements; Id. No. GW-20 and CR-12 through CR-17).

- Develop numerical biological fate and transport models for application to specific contaminants and specific species of interest for long-term river impacts assessment (Columbia River technical element; Id. No. CR-20).

- Develop credible models (hydrodynamic, sediment, and contaminant) to describe and predict contaminant migration and fate in the river environment (Columbia River technical element; Id. No. CR-18 through CR-21).

3.6 S&T LINKAGES TO THE GROUNDWATER PROJECT

Groundwater Project: S&T activities will be coordinated with the Groundwater Project to obtain key data or test models.

The Groundwater Project is conducted to meet regulatory requirements, and to support individual projects in obtaining important data for project-specific objectives. To meet these goals, data quality objectives with input from all interested site projects are established annually for new wells. Coordination of S&T tasks with planning for groundwater monitoring provide an opportunity to obtain key field data for both the vadose zone and groundwater technical elements. The Groundwater Project also develops and applies groundwater models that are important to the S&T activities and will be used by the SAC. The following S&T activities have been identified for coordination with the Groundwater Project. (*Note*: A more complete description of the S&T outcomes, interfaces, and schedules can be found in Section 4.0 [Table 4-1]. The Id. No. for each S&T outcome is listed in parentheses below to aid the reader in identifying the S&T outcomes [in Table 4-1] that provide input to the groundwater monitoring project.)

- Coordinate reevaluation of existing data, depth-discrete sampling, and observation of a developing tritium plume from soil disposal sites and tank farms (groundwater technical element; Id. No. GW-1 through GW-4).

- Define the objectives and implementation of 3D monitoring, as needed, to support the SAC and selected S&T investigations (groundwater technical element; Id. No. GW-8 through GW-13).

- Deploy advanced characterization and monitoring tools for vadose zone and groundwater (vadose zone technical element; Id. No. VZ-25 and VZ-26).

In the future, the S&T activities specific to the monitoring technical element will be further defined. At that time, S&T will be integrated with the groundwater monitoring project to provide 1) technical support for advanced technologies associated with sampling and analysis (e.g., advanced sensors), 2) development and application of advanced monitoring strategies (e.g., use of stable isotope geochemistry, waste-specific fingerprints), and 3) application of predictive modeling to support monitoring network design.

3.7 S&T LINKAGES TO ILAW PROJECT

Immobilized Low-Activity Waste (ILAW) Project: A selected set of S&T activities may be conducted in conjunction with the field activities conducted for the ILAW to obtain key data or test models.

The RPP ILAW facilities, which will be located in the 200 East Area, will receive the low-activity waste form generated from treated and immobilized tank waste. The construction decision for this facility is scheduled for FY03. Current field and S&T activities carried out as part of the ILAW project are directed at gathering the information needed to conduct performance assessments that support this decision, including data on geology, recharge rates, near-field and far-field hydraulic properties, and near-field and far-field geochemical properties. The ILAW project is also gathering information on available contaminant transport codes, and is working to define conceptual and numerical models. The Integration Project S&T activities do not currently directly link with ILAW project activities, but coordinate activities on:

- Wrap-around science (as appropriate) to obtain geology, near- and far-field hydrology, and near- and far-field geochemistry data that can be used in conceptual and numerical modeling to the mutual benefit of the ILAW project, the SAC, and the S&T endeavor

- Reactive transport modeling to the mutual benefit of the ILAW project, the SAC, and the S&T endeavor.

4.0 SCHEDULE OF S&T ACTIVITIES AND PRODUCTS

This section presents detailed programmatic information on the scope and schedule of S&T outcomes, along with linkages to the core projects. These linkages are shown in Figure 4-1 and Table 4-1. The schedule for key S&T outcomes has been linked to the SAC and core project schedules, as shown in the Integration Project's *Long-Range Plan* (LRP). The LRP is a separate document from the Project Description. It contains a graphic presentation of schedules, products, and interfaces between the core projects, SAC, S&T, and the Integration Project. Figure 4-1 presents a summary level graphic presentation of the *Long-Range Plan* for only the S&T activities, which are organized by technical elements.

The programmatic information shown in Figure 4-1 includes the S&T products through identification numbers that correspond to an explanation of scope and outcome in Table 4-1. Figure 4-1 also includes schedule and linkages of the S&T products to the SAC and core projects that are shown by "down triangles" and "up triangles," respectively. The S&T products that link to other S&T activities are depicted by circles (the actual linkages are shown in the more detailed LRP, but are not shown in Figure 4-1). Within each of these symbols, numbers are provided to link back to Table 4-1. The products numbered 1 through 23 in the "Inventory" section of Figure 4-1 correspond to identification numbers Inv-1 through Inv-23 in Table 4-1. Likewise, products numbered 1 through 27 in the section of Figure 4-1 labeled "Vadose Zone" correspond to identification numbers VZ-1 through VZ-27 in Table 4-1. Products numbered 1 through 20 in the section of Figure 4-1 labeled "Groundwater" correspond to identification number GW-1 through GW-20 in Table 4-1. Products labeled 1 through 21 in the section of Figure 4-1 labeled "Columbia River" correspond to identification numbers CR-1 through CR-21 in Table 4-1. Products labeled 1 through 24 in the section of Figure 3-1 labeled "Risk" correspond to identification numbers R-1 through R-24 in Table 4-1. Lines are shown for the "monitoring" and "remediation" elements, with the EMSP and other contributions included. Table 4-1 includes one entry for the monitoring technical element and two entries for the remediation technical element. These technical elements will be expanded during planned revisions of the roadmap in FY01 and 2002.

The EMSP projects from the FY99 awards that contribute to the S&T endeavor are shown in circles on the roadmap, identified by EMSP project number. The circles denote that they feed outcomes to another S&T activity. For this revision of the roadmap, the EMSP outcomes are shown in the third year of the projects (FY02). The outcomes (timing and products) for the EMSP projects will be refined through the science/user teams and updated in future revisions of the roadmap.

The products are also colored in Figure 4-1 to indicate project leads. Red coloration refers to an S&T activity that will be carried out through a core project. An example is the "unplanned releases" scope that is being conducted by the RPP Vadose Zone Project (e.g., Inv-1 through Inv-3). Because the outcome of this work is highly relevant to the S&T and SAC efforts, and requires strong technical integration, it is included in the S&T roadmap for completeness. Blue coloration refers to an S&T activity that is led predominantly by scientists and is likely to have strong interaction with DOE National S&T Programs (such as the DOE EMSP).

Brown coloration indicates that the lead for the S&T activity is within an EMSP project and linkage to the Integration Project is done through the S&T endeavor. Green coloration refers to an S&T activity that is leveraged with a core project activity. An example is the field investigations of representative sites (e.g., VZ-1, VZ-3, and VZ-4) being conducted jointly by the RPP Vadose Zone Project, Groundwater Project, and the S&T component of the Integration Project. The RPP is conducting field characterization in the tank farms that is needed to meet data quality objectives for corrective measures of these facilities per *Resource Conservation and Recovery Act of 1976* (RCRA) requirements for treatment, storage, and disposal facilities. The Groundwater Project is placing RCRA monitoring wells near the tank farms undergoing characterization, and is providing monitoring of groundwater plumes. Both S&T and the RPP have acquired samples from the RCRA wells. RPP has an interest in the geology and stratigraphy, while S&T is using the soil samples to conduct laboratory studies that elucidate key information needed to understand the controlling mechanisms for contaminant movement. The S&T endeavor is also conducting analyses on samples taken by RPP from boreholes in the contaminated vadose zone. All three projects will work together to interpret the data, develop conceptual models, and provide data to their respective users and decision makers.

Table 4-1 contains descriptions of the activities in Figure 4-1. The product identification numbers shown in Figure 4-1 (e.g., Inv-1, VZ-1) correspond directly to the identification numbers in Table 4-1. For each identification number, the following information is provided in Table 4-1:

- Technical element – inventory, vadose zone, groundwater, and Columbia River – used commonly in the LRP and draft S&T Plan.

- S&T activity within the technical element – broad categories of S&T activities within each technical element.

- Descriptive (and unique) title for each S&T product shown by identification number in Figure 4-1, and also used in the text box of the LRP (e.g., informally referred to as the project and S&T roadmap charts).

- Brief description of scope and outcome for each S&T product shown in Figure 4-1 corresponding to the product identification number (e.g., Inv-1, etc.). (This scope and description can be crosswalked to the LRP through the product identification number and the descriptive title that are common to Table 4-1, Figure 4-1, and the text box in the LRP.)

- Identification of the integrated need by "RL" number and associated title to which this S&T outcome responds. The need number and title provided in the table correspond to the full need information that is provided in Appendix B.

- Identification of the projects or other S&T activities for which integration or coordination is needed to conduct the S&T activity and generate the desired product.

- Identification of the recipient (or customer) for the S&T product.

- Date that startup is needed for the overall S&T activity within each technical element to meet project schedules.

- The S&T product delivery date, assuming the startup date is met, is provided in accordance with the established schedule.

Figure 4-1. Applied Science and Technology Schedule, Logic, and Linkages. (2 Pages)

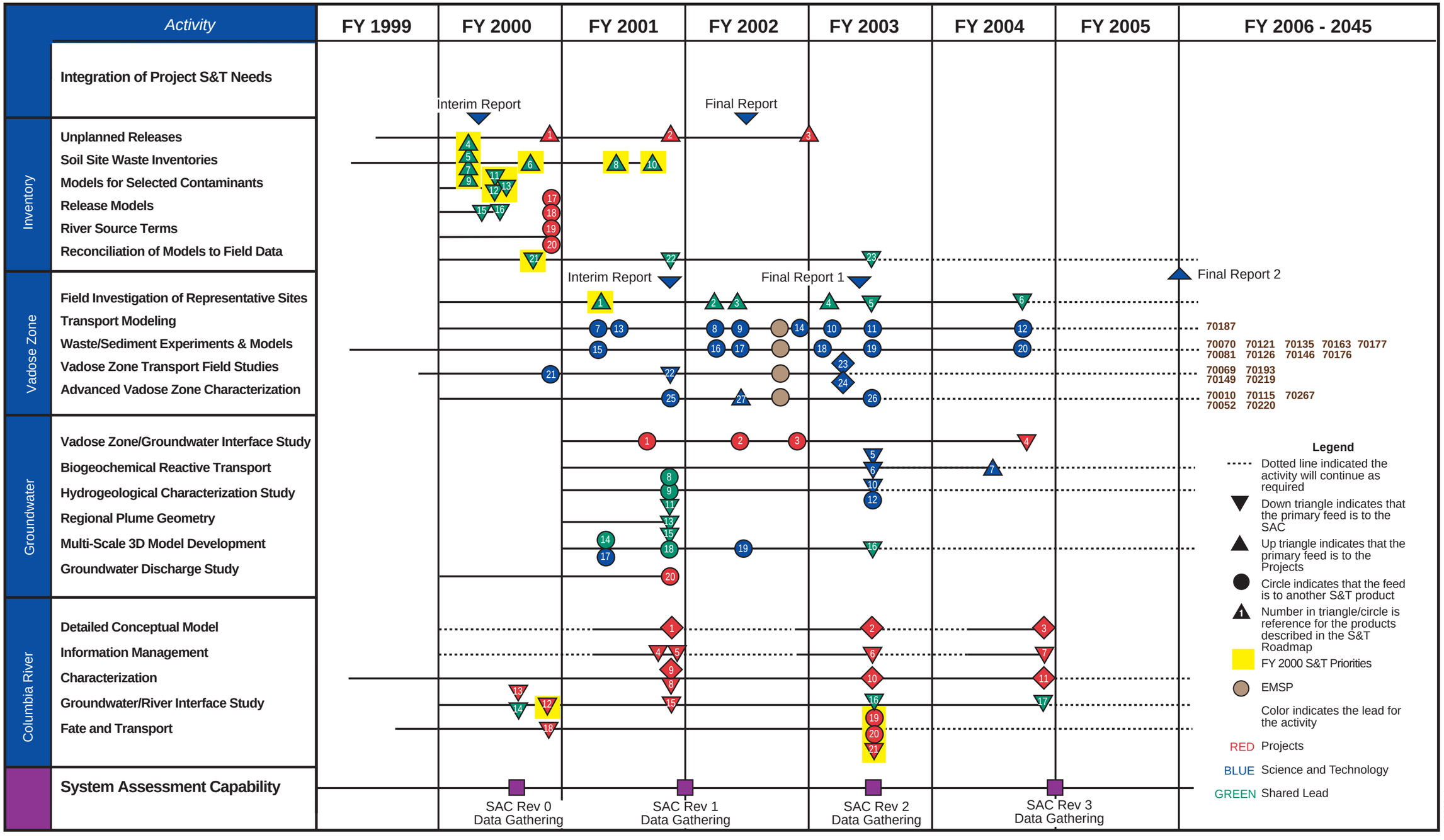


Figure 4-1. Applied Science and Technology Schedule, Logic, and Linkages. (2 Pages)

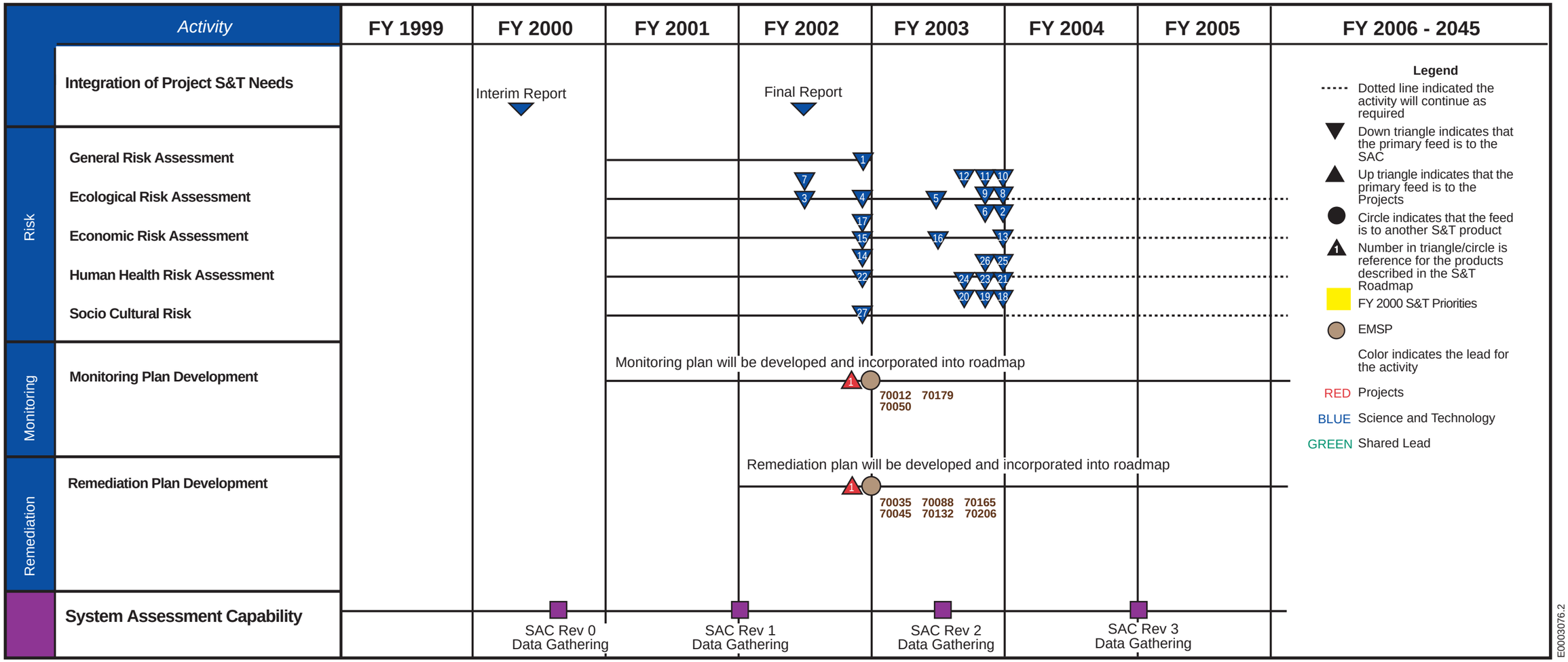


Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inventory Technical Element								
Inv-interim report	Soil Site Waste Inventory	Intermediate Inventory	The scope of this activity is to develop contaminant and volume inventories for each of the soil site groups at the Hanford Site. The outcome will be a report that captures preliminary contaminant and volume inventories for soil waste groups specified by the SAC, Rev. 0.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC to define and prioritize waste site groupings and contaminants	SAC, Rev. 0	June 99	Feb 00
Inv-final report	Soil Site Waste Inventory	Soil Site Waste Inventory	The scope of this activity is to develop contaminant and volume inventories for each of the soil site groups at the Hanford Site. Along with this information, a timeline for each release to soil expressed as kgal/qtr (1,000 gal per calendar quarter) will be developed. The outcome will be a report that captures soil site inventories for the SAC, Rev. 1.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC to define and prioritize waste site groupings and contaminants	SAC, Rev. 1	Mar 00	Mar 02
Inv-1	Unplanned Releases	Boiling Waste Tanks (S, SX) Model	The scope of this activity is to estimate volume and waste composition for unplanned releases from boiling waste tanks that have particular attributes of high temperature, violent bumping, and self-sealing due to high salt content contributing to unique leak characteristics. The outcome will be documented inventory estimates.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	RPP Vadose Zone Project (Lead)	RPP Vadose Zone Project and Inv-interim report	Jan 98	Apr 00
Inv-2	Unplanned Releases	High-Level Waste Leaks (B, BX, BY) Model	The scope of this activity is to estimate volume and waste composition for unplanned releases from dilute waste tanks. For these tanks with low salt contents and low heat content, more traditional modes of failure and leaking (such as stress corrosion cracking) occur. The low reactivity of these wastes with soil suggests that self-sealing is not an issue. The outcome will be documented estimates for dilute waste tank leaks.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	RPP Vadose Zone Project (Lead)	RPP Vadose Zone Project and Inv-final report	Oct 00	Sep 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-3	Unplanned Releases	High-Level Tank Leak (T, TX, TY) Model	The scope of this activity is to estimate volume and waste composition for unplanned releases from concentrated waste tanks. Waste concentrates were created by active evaporation inside and outside of tanks. The resulting high-salt slurries were prone to self-sealing, had moderate temperatures, and high sodium hydroxide content that affects leak waste composition. The outcome will be documented inventory estimates for concentrated waste tank leaks.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	RPP Vadose Zone Project (Lead)	RPP Vadose Zone Project	Oct 01	Sep 02
Inv-4	Soil Site Waste Inventory	Plant Cooling Water Model, Rev. 0	The scope of this activity is to provide the methodology and preliminary estimates of contaminant inventories and physical properties of plant cooling water discharges with uncertainties to support sitewide assessment through the SAC. The outcome will be documented estimates for PUREX and B Plants.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project	200 Area Remedial Action Project, Inv-interim report, and Inv–6 Complete	June 99	Feb 00
Inv-5	Soil Site Waste Inventory	Chemical Sewer Model, Rev. 0	The scope of this activity is to provide the methodology and preliminary estimates of contaminant inventories and physical properties of chemical sewer discharges with uncertainties to support sitewide assessment through the SAC. These estimates will be for PUREX and B Plants. The outcome will be documented preliminary estimates of chemical sewer discharges.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project	200 Area Remedial Action Project, Inv-interim report, and Inv–6 Complete	June 99	Feb 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-6	Soil Site Waste Inventory	Chemical Sewer and Plant Cooling Water Models, Rev. 1	The scope of this activity is to provide the updates to the methodology and estimates for separation plant chemical sewers based on fractions of plant chemicals used and for cooling water based on extrapolations of reported contamination events. The outcome will be revised estimates of discharges from the PUREX and B Plant chemical sewers and will include Redox, T, and U Plant cooling water discharges. In particular, the UO_3 Plant seems to have placed uranium along with Tc-99 and chemicals in disposal cribs.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project	200 Area Remedial Action Project and Inv-final report	Mar 00	Aug 00
Inv-7	Soil Site Waste Inventory	Scavenging Waste Model, Rev. 0	The scope of this activity is to provide the methodology and preliminary estimate of contaminant inventories and physical properties of scavenging waste supernatants from the ferrocyanide scavenging of Cs-137 in the late 1950's to support sitewide assessment through SAC. Tc-99 and Co-60 were placed into the disposal cribs during this campaign. The outcome will be documented estimates of scavenging waste inventories.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project	200 Area Remedial Action Project, Inv-final report, and Inv-8 Complete	June 99	Feb 00
Inv-8	Soil Site Waste Inventory	Scavenging Waste Model, Rev. 1	The scope of this activity is the same as Inv-7. This outcome will provide updates to the methodology and estimates developed in Inv–7, based on quantity and importance of Tc contribution from the BC cribs.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project	200 Area Remedial Action Project and Inv-final report	Mar 00	Mar 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-9	Soil Site Waste Inventory	Surface Spill Model, Rev. 0	The scope of this activity is to provide the methodology and preliminary estimates of contaminant inventories and physical properties for the BX-102 surface spill in 1952 to support sitewide assessment through the SAC. This spill placed 90 kgal of mixed waste into the soil column around BX-102 by inadvertent overfill of the tank. This outcome will be documented estimates of surface spill inventories for BX-102.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project, RPP Vadose Zone Project	RPP Vadose Zone Project, Inv-interim report, and Inv–10 Complete	June 99	Feb 00
Inv-10	Soil Site Waste Inventory	Surface Spill Model, Rev. 1	The scope of this activity is the same as Inv-9. This outcome will provide an update to the methodology and estimates with other significant surface spills such as the 242-T Evaporator in 1975.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	200 Area Remedial Action Project, RPP Vadose Zone Project	200 Area Remedial Action Project and Inv-final report	Mar 00	Aug 01
Inv-11	Models for Selected Contaminants	Tc-99 Model	The scope of this activity is to provide a methodology to describe the distribution of Tc-99 as input to waste type models needed for mass balanced sitewide assessments through the SAC. Building off the Tc-99 mass balance work conducted by RPP in FY99, the amount and distribution of Tc-99 among the tanks and cribs, and that co-mingled with the uranyl nitrate sent to UO_3 will be derived along with a representative uncertainty. The outcome will be documented estimates of Tc-99 mass balance for input to waste type models. The Tc-99 inventory estimates and uncertainty will be incrementally refined as more waste streams are identified and incorporated into the inventory model.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC, RPP Vadose Zone Project, and 200 Area Remedial Action Project	SAC, Rev. 0 Complete	Oct 99	Feb 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-12	Models for Selected Contaminants	Tritium Soil Model	The scope of this activity is to provide a methodology to describe the distribution of tritium as input to waste type models needed for mass-balanced sitewide assessments through the SAC. Extensive historical records of tritium in groundwater provide the largest single information source for large-scale contaminant distributions in groundwater. The outcome of this activity will be a documented history of tritium placed into condensate cribs from plant and tank evaporation losses. The tritium inventory will be incrementally refined as more waste streams are incorporated into the inventory model.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC and 200 Area Remedial Action Project	SAC, Rev. 0 Complete	Oct 99	Feb 00
Inv-13	Models for Selected Contaminants	I-129 Model, Rev. 0	The scope of this activity is to provide the inventories and uncertainties associated with I-129 in the waste streams developed in the Soil Inventory tasks (Inv-4, 5, & 7) as input to waste type models needed for mass-balanced sitewide assessments through SAC, Rev. 0.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC	SAC, Rev. 0	Oct 99	Sep 00
Inv-14	Models for Selected Contaminants	I-129 Model, Rev. 1	The scope of this activity is to provide the inventories and uncertainties associated with I-129 as input to waste type models needed for mass-balanced sitewide assessments through SAC, Rev. 1. This task will build on the initial SAC, Rev. 0 and Rev. 1 Soil Inventory tasks, as well as incorporate findings from task Inv-16 (I-129 Saddles model), unplanned releases tasks (Inv-1, 2, 3), best-basis inventory (SST & DST inventories) and the Hanford Environmental Dose Reconstruction Project (airborne releases). The outcome will be documented, mass-balanced I-129 inventories with uncertainties.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC	SAC, Rev. 1	Oct 00	Aug 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-15	Release Models	Solid Waste Release Model	The scope of this activity is to provide a release model for residual contamination released from solid waste burial sites to support sitewide assessments through the SAC. The pre-1970 sites with high TRU wastes that were segregated will be included in this release model. The outcome will be a documented release model from solid waste burial sites.	RL-SS42 – Provide method for more accurate estimates of waste constituent release rates and modes from waste.	SAC (Lead) and 200 Area Remedial Action Project	SAC, Rev. 0	Oct 99	Sep 00
Inv-16	Release Models	I-129 Saddles Model	The amount of I-129 that remained with the scrubber saddles is highly uncertain. The scope of this activity is to define the remnant I-129 inventory and describe its long-term release to support sitewide assessments through the SAC. The outcome will be a documented inventory and projected release of I-129 from the scrubber saddles.	RL-SS42 – Provide method for more accurate estimates of waste constituent release rates and modes from waste.	SAC (Lead)	SAC, Rev. 0	Oct 99	Sep 00
Inv-17	River Source Term	Cr Sources	The scope of this activity is to determine the quantity of chromium that has and will be released to the river. Chromium additions to reactor cooling water were used to control corrosion and ended up in the soils, river sediments, and groundwater around each reactor. The outcome will be documented estimates of chromium releases to the river.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC (Lead) and River Monitoring Project	CR-1 Complete	Oct 99	Sep 00
Inv-18	River Source Term	Sr-90 at N Springs	The amounts of Sr-90 at N Springs are associated with reactor fuel element breaches. Along with Sr-90, other fission products were lost to the cooling water. The scope of this activity is to recover the suite of fission products that may be present at N Springs. The outcome will be a documented inventory and release of Sr-90 at N Springs to the river.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC (Lead) and River Monitoring Project	CR-1 Complete	Oct 99	Sep 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-19	River Source Term	Co-60 Model	The scope of this activity is to determine the quantity of Co-60 released to the river. The activation of cobalt impurities in steel cooling coils and its subsequent loss as a result of corrosion has left Co-60 residues in the cooling water for each reactor. The outcome will be documented estimates of Co-60 releases to the river.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC (Lead) and River Monitoring Project	CR-1	Oct 99	Sep 00
Inv-20	River Source Term	Tritium River Source	The scope of this activity is to determine the quantity of tritium released to the river. The activation of cooling water to tritium by each reactor resulted in production of large amounts of tritium. This tritium was placed into holding basins and eventually the Columbia River or soil column at the river. The outcome will be documented estimates of tritium releases to the river.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	SAC (Lead) and River Monitoring Project	CR-1	Oct 99	Sep 00
Inv-21	Reconciliation of Model and Field Data	Reconcile Inventory, Rev. 0	The scope of this activity is to provide reconciliation of field and model data to update the methodology for estimating releases to soil, allowing for mass balance and uncertainty to support future sitewide assessments through the SAC. Initially, this scope will reconcile the inventory estimates with the historical process records in an attempt to better refine the uncertainty for each soil site group. The outcome will be a documented methodology for reconciling inventory field data and model estimates for the SAC, Rev. 0.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	All S&T Technical Elements and Core Projects	SAC, Rev. 0	Oct 99	May 00
Inv-22	Reconciliation of Model and Field Data	Reconcile Inventory, Rev. 1	The scope of this activity is the same as Inv-21. The outcome will be a documented update to the methodologies for reconciling field data and model estimates for the SAC, Rev. 1.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	All S&T Technical Elements and Core Projects	SAC, Rev. 1	Jan 00	Oct 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Inv-23	Reconciliation of Model and Field Data	Reconcile Inventory, Rev. 2	The scope of this activity is the same as Inv-21 and Inv-22. The outcome will be an update for the SAC, Rev. 2.	RL-SS40 – Provide a method to develop mass balance (i.e., holistic) inventory estimates.	All S&T Technical Elements and Core Projects	SAC, Rev. 2	Oct 02	Apr 03
Vadose Zone Technical Element								
VZ-interim report	Vadose Zone Technical Element	Interim Input to SAC for 200 Area Remedial Action Decisions	The scope of this activity is to develop enhanced understanding of controlling features and processes affecting flux of contaminants through the vadose zone, and to document these results in improved conceptual and numerical models. The outcome will be documented results to support SAC, Rev. 1.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and to allow improved future projections.	SAC, RPP Vadose Zone Project, 200 Area Remedial Action Project, and EMSP	SAC, Rev. 1	Oct 99	Sep 01
VZ-final report 1	Vadose Zone Technical Element	Tank Farm Assessment Tools to Support SST Retrieval and Tank Closure Decisions	The scope of this activity is the same as VZ-Final Report 1. The outcome will be an update for SAC, Rev. 2.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and to allow improved future projections.	SAC, RPP Vadose Zone Project, and EMSP	SAC, Rev. 2	Oct 01	Feb 03
VZ-Final report 2	Vadose Zone Technical Element	Models for 200 Area Waste Sites, Including Tank Farm Closure and Soil Remediation	The scope of this activity is to provide a capability to simulate water and contaminant migration (immobilization, remobilization, etc.) in waste cribs and retention basins in the Hanford Site 200 Areas. The outcome will be a documented suite of conceptual and numerical models, associated data bases, and advanced characterization methods.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and to allow improved future projections.	SAC, 200 Area Remedial Action Project, and RPP Vadose Zone Project	RODs for 200 Area Remedial Action Project	Mar 03	Sep 08

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-1	Field Investigations of Representative Sites	Preliminary Conceptual Models – WMA S-SX	The scope of this activity is to provide an understanding of important geochemical, hydrologic, and hydrochemical processes below boiling waste tanks by studying uncontaminated and contaminated core material from WMA S-SX in collaboration with the RPP ("wrap around" science near SX-108 and SX-115). The scope includes determination of minerologic association of Tc and Cs, determination of whether new minerological phases have resulted from waste-sediment interactions, and establishing the impact of high salinity/caustic solutions on hydraulic properties of the soils beneath tanks. The outcome will be a documented suite of conceptual models for key processes and associated databases for WMA S-SX.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and projections of future behavior.	RPP Vadose Zone Project, Inventory, Waste Sediment Lab Experiments and Process Modeling, and Transport Modeling S&T Activities, EMSP	VZ – Final Report and S-SX Field Report for RPP Vadose Zone Project	Oct 99	Oct 01
VZ-2	Field Investigations of Representative Sites	Preliminary Conceptual Models – 200 Area Soil Waste Sites	The scope of this activity is to develop an understanding of important geochemical, hydrologic, and hydrochemical processes at 200 Area soil waste sites by studying contaminated soil samples from cribs, specific retention trenches, and ditches to test alternative conceptual models ("wrap around" science). Scope includes evaluation of which contaminants are immobilized, and by what reaction, and which are still liable for transport. Sites that received significant inventories of Tc and low volumes of liquids (scavenged wastes), Pu, Am, and Np (Z-11), or DNAPLs (Z-9) will be emphasized. The outcome is a documented suite of conceptual models of key processes and associated databases for the appropriate waste site grouping.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and projections of future behavior.	200 Area Remedial Action Project, Inventory, Transport Modeling, and Waste Sediment Lab Experiments and Process Modeling S&T Activities, EMSP	VZ-Interim Report, and 200 Area Remedial Action Project	Jan 01	Jan 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-3	Field Investigations of Representative Sites	Preliminary Conceptual Models – WMA B-BX-BY	The scope of this task is to develop an understanding of important geochemical, hydrologic, and hydrochemical processes below dilute waste tanks by studying contaminated material from tank farm boreholes to test alternative conceptual models ("wrap around" science at BX-102). Examples include 1) determination of whether presumed mobile and conservative HLW indicators such as pertechnetate show any evidence for reduction to insoluble oxides by electron dense solids in sediment, or 2) hydrogeochemical processes controlling U distribution and future mobility. The outcome will be a documented suite of conceptual models of key processes and associated databases for WMA B-BX-BY.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and projections of future behavior.	RPP Vadose Zone Project, Inventory, Transport Modeling, and Waste Sediment Lab Experiments and Process Modeling S&T Activities, EMSP	Input to Product VZ – Final Report 1 and B-BX-BY Field Report for RPP Vadose Zone Project	Oct 01	Jun 01
VZ-4	Field Investigations of Representative Sites	Preliminary Conceptual Models – Concentrated HLW Waste Tanks and Key 200 Area Soil Sites	The scope of this activity is to develop a practical understanding of important chemical and hydrologic processes that control contaminant distributions and future contaminant behavior beneath leaked, concentrated HLW tanks (e.g., TX) and a soil waste site under characterization by the 200 Area Remedial Action Project. The outcome will be a documented suite of conceptual models of key processes and associated databases for concentrated HLW tanks, such as TX and the studied 200 Area soil waste site grouping.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution and projections of future behavior.	RPP Vadose Zone Project, 200 Area Remedial Action Project Inventory, Transport Modeling , and Waste Sediment Lab Experiments and Process Modeling S&T Activities, EMSP	VZ-Final Report 1, RPP Vadose Zone Project, 200 Area Remedial Action Project	Oct 00	Jul 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-5	Field Investiga-tions of Representative Sites	Conceptual Models for Input to SAC, Rev. 2	The scope of this activity is to develop a comprehensive understanding of important processes controlling contaminant distribution beneath leaked SSTs containing different waste types in different geologic zones. The outcome will be a documented suite of conceptual models of key processes controlling SST leaks and associated databases for input to the SAC, Rev. 2.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution.	SAC, RPP Vadose Zone Project, Transport Modeling, and Waste Sediment Lab Experiments and Process Modeling S&T Activities, EMSP	SAC, Rev. 2, VZ Final Report 1	Feb 01	Feb 03
VZ-6	Field Investiga-tions of Representative Sites	Conceptual Models for Input to SAC, Rev. 3	The scope of this activity is to develop a comprehensive understanding of important processes controlling contaminant distributions beneath leaked SSTs containing different waste types in different geologic zones. The outcome will be a documented suite of conceptual models of SST leaks for the SAC, Rev. 3.	RL-SS27 – Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution.	SAC, RPP Vadose Zone Project, and 200 Area Remedial Action Project	SAC, Rev. 3, VZ Final Report 2	Aug 02	Aug 04
VZ-7	Transport Modeling	Preliminary Modeling of Subsurface Processes - WMA S-SX	The scope of this activity is to provide a preliminary evaluation of key transport processes beneath high-priority tanks in WMA S-SX. Simulations of nonisothermal fluid flow, mineral reactions, and contaminant sorption will integrate new and existing data and test alternative conceptual models of important transport processes. The outcome will be a documented suite of process models and simulation results for WMA S-SX.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, RPP Vadose Zone Project, SAC, EMSP	VZ-1	Jan 00	Oct 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-8	Transport Modeling	Preliminary Modeling of 200 Area Soil Waste Sites	The scope of this activity is to provide a preliminary evaluation of key transport processes at high-priority 200 Area soil sites. Simulations of fluid flow with multicomponent chemical reactions will integrate new and existing data and conceptual models of important transport processes. The outcome will be a documented suite of process models and simulation results for 200 Area soil waste sites.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Inventory, Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, 200 Area Remedial Action Project, SAC, EMSP	VZ-2	Feb 01	Jan 02
VZ-9	Transport Modeling	Preliminary Modeling of Subsurface Processes - WMA B-BX-BY	The scope of this activity is to provide a preliminary evaluation of key transport processes affecting contaminant migration at WMA B-BX-BY. Simulations of fluid flow and multicomponent reactive transport will integrate new and existing data and test alternative conceptual models of important transport processes. The outcome will be a documented suite of process models and simulation results for WMA B-BX-BY.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, RPP Vadose Zone Project, SAC	VZ-3	Feb 01	Jun 01
VZ-10	Transport Modeling	Preliminary Modeling of Subsurface Processes - WMA T-TX-TY	The scope of this activity is to provide a preliminary evaluation of key transport processes affecting contaminant migration at WMA T-TX-TY. Simulations of fluid flow and multicomponent reactive transport will integrate new and existing data and test alternative conceptual models for contaminant mobility. The outcome will be a documented suite of process models and simulation results for WMA T-TX-TY	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, RPP Vadose Zone Project, SAC, EMSP	VZ-4, RPP Vadose Zone Project	Feb 01	Jul 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-11	Transport Modeling	Modeling Analyses for Rev. 2 of the SAC	The scope of this activity is to provide Rev. 2 of the SAC with evaluations of key contaminant transport processes beneath SSTs. The analyses will guide 1) vadose zone contaminant source terms and/or transfer functions, and 2) the use of simplifying assumptions in large-scale modeling. The outcome will be a documented suite of process models and simulation results for SAC, Rev. 2.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, RPP Vadose Zone Project, SAC	VZ-5, SAC, Rev. 2	Feb 01	Feb 03
VZ-12	Transport Modeling	Modeling Analyses for Rev. 3 of the SAC and the RPP RFI	The scope of this activity is the simulation of coupled fluid flow and multicomponent reactive transport beneath HLW tanks. These comprehensive simulations will support Rev. 3 of the SAC with evaluations of key contaminant transport processes. The outcome will be a documented suite of process models and simulation results for SAC, Rev. 3, and the RPP RFI.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Field Investigations of Representative Sites and Vadose Zone Transport Field Studies S&T Activities, RPP Vadose Zone Project, SAC	VZ-6, SAC, Rev. 3	Aug 02	Oct 03
VZ 13	Transport Modeling	Modeling Analyses for Vadose Zone Reactive Transport Field Study at 200 East Area Surrogate Site	The scope of this activity is to perform simulations to assist experimental design of the field-scale infiltration and reactive tracer experiments at a tank farm surrogate site in the 200 East Area. The outcome will be a documented suite of process models and simulation results to support field test design.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Vadose Zone Transport Field Study and Advanced Characterization S&T Activities, RPP Vadose Zone Project	VZ-22	Oct 00	Mar 01
VZ-14	Transport Modeling	Modeling Analyses for Vadose Zone Reactive Transport Field Study in 200 West Area Sediments	The scope of this activity is to perform simulations to assist experimental design of the field-scale infiltration and reactive tracer experiments at a site in the 200 West Area. The outcome will be a documented suite of process models and simulation results to support field test design.	RL-SS29 – Develop descriptions of contaminant flow and transport in the vadose zone.	Vadose Zone Transport Field Studies and Advanced Characterization S&T Activities, RPP Vadose Zone Project	VZ-24	Oct 01	Sep 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-15	Waste-Sediment Lab Expts & Process Models	Interim Data WMA S-SX	The scope of this activity is to develop an improved understanding of the geochemistry in S-SX Tank Farm by conducting kinetic and thermodynamic studies for key contaminants (such as Cs and Tc) using contaminated and uncontaminated tank farm sediments to determine first-order chemical and hydrochemical reactions under extreme conditions of boiling waste tank leaks (e.g., SX-118). The outcome will be a documented suite of interim laboratory data for WMA S-SX to support improved long-term predictions of future contaminant behavior.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities and RPP Vadose Zone Project, EMSP	VZ-1	Oct 99 (Some tasks ongoing through EMSP)	Feb 01
VZ-16	Waste Sediment Lab Expts & Process Models	Interim Data 200 Area Waste Sites	The scope of this activity is to develop an improved understanding of key geochemical phenomena at scavenging waste, U Pond, Z-9, or Z-11 soil sites by conducting kinetic and thermodynamic studies for contaminants of concern using uncontaminated or contaminated sediments to determine first-order chemical and hydrochemical reactions under dilute conditions. The outcome will be a documented suite of interim laboratory data that can be used to support improved predictions of future contaminant behavior.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities, 200 Area Remedial Action Project, EMSP	VZ-2, 200 Area Remedial Action Project	Jan 01	Jan 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-17	Waste-Sediment Lab Expts & Process Models	Interim Data WMA B-BX-BY	The scope of this activity is to develop an improved understanding of key geochemical phenomena at B-BX-BY Tank Farms (with special interest in BX-102) by conducting kinetic and thermodynamic studies for contaminants of concern using contaminated and uncontaminated sediments to determine first-order chemical and hydrochemical reactions under dilute tank waste conditions. The outcome will be a documented suite of laboratory data for WMA B-BX-BY that can be used to support improved prediction of future contaminant behavior.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities and RPP Vadose Zone Project, EMSP	VZ-3	Oct 00	Jun 01
VZ-18	Waste-Sediment Lab Expts & Process Models	Interim Data Concentrated HLW Waste Tanks and Key 200 Area Soil Sites	The scope of this activity is to develop laboratory kinetic and thermodynamic data on selected contaminants and first order chemical and hydrochemical reactions and processes in contaminated and uncontaminated sediments directed at leaked, concentrated HLW waste tanks (e.g., TX) and at key soil waste sites. The outcome will be a documented suite of laboratory data to allow improved projections of future contaminant migration or solubility.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities and RPP Vadose Zone Project, and 200 Area Remedial Action Project, EMSP	VZ-4	Oct 00	Nov 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-19	Waste-Sediment Lab Expts & Process Models	Process Models and Data – WMAs S-SX, B-BX-BY, T-TX-TY	The scope of this activity is to develop numerical models of first-order hydrochemical processes controlling future contaminant behavior. Descriptive thermodynamic and kinetic data will be applied to unsaturated flow columns representative of in-ground contaminant associations resulting from dilute, concentrated, and boiling tank releases. The outcome will be a documented suite of laboratory experiments and process models to project future contaminant migration at the various tank farms.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities, RPP Vadose Zone Project, EMSP	VZ-5	Oct 01	Feb 03
VZ-20	Waste-Sediment Lab Expts & Process Models	Process Models and Data – Representative Soil Site Groupings	The scope of this activity is to develop numerical models of first-order hydrochemical processes controlling future contaminant behavior. Descriptive thermodynamic and kinetic data will be applied to unsaturated flow columns representative of in situ contaminant associations at key soil waste sites. The outcome will be a documented suite of laboratory experiments and process models to predict future contaminant migration at representative soil sites.	RL-SS28 – Understand, quantify, and develop descriptions of reactions and interactions between contaminants of concern and vadose and sediments.	Field Investigations of Representative Sites and Transport Modeling S&T Activities, 200 Area Remedial Action Project, EMSP	VZ-6	Oct 02	Aug 04
VZ-21	Vadose Zone Transport Field Studies	Leak Experiments for Tank Farm Surrogate Site in 200 East Area	The scope of this activity is to conduct field studies to develop an understanding of field-scale water and solute movement in heterogeneous Hanford Site sediments at a well-characterized site. The outcome will be a documented set of field experiments and data sets for the 200 East Area that will be used for vadose zone parameter estimation, model verification, and history matching.	RL-SS30 – Understand and quantify movement in the vadose zone using uncontaminated field sites.	SAC, RPP Vadose Zone Project, Transport Modeling and Advanced Characterization, Field Investigations of Representative Sites S&T Activities, EMSP	VZ-22, SAC, Rev. 0	May 00	Sep 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-22	Vadose Zone Transport Field Studies	Field Scale Verification of Reactive Transport, Tank Farm Surrogate Site in 200 East Area	The scope of this activity is to conduct field studies to develop an understanding of field-scale reactive transport through the vadose zone at the Hanford Site. Infiltration and reactive tracer experiments will be used to describe water movement and reactive solute transport at the site used in VZ-20. The outcome will be a documented set of field experiments and data sets for reactive transport in the 200 East Area that will be used for vadose zone parameter estimation, model verification, and history matching.	RL-SS30 – Understand and quantify movement in the vadose zone using uncontaminated field sites.	SAC, RPP Vadose Zone Project, Transport Modeling and Advanced Characterization, Field Investigations of Representative Sites S&T Activities, EMSP	SAC, Rev. 1, VZ-Interim Report, and VZ-11	Sep 00	Sep 01
VZ-23	Vadose Zone Transport Field Studies	Variable Infiltration Experiments – 200 West Area Deep Sediments	The scope of this activity is to conduct field experiments demonstrating water migration pathways in vadose zone geologies associated with both leaking tanks and specific retention basins where variable infiltration dominates the flow process in highly heterogeneous flow systems that are under-characterized. The outcome will be a documented set of field experiments and data sets for the 200 West Area that will be used for vadose zone parameter estimation, model verification, and history matching.	RL-SS30 – Understand and quantify movement in the vadose zone using uncontaminated field sites.	SAC, RPP Vadose Zone Project and Advanced Characterization, Field Investigations of Representative Sites S&T Activities, EMSP	SAC, Rev. 2, 200 Area Remedial Action Project, RPP Vadose Zone Project, and VZ-24	Oct 01	Feb 03
VZ-24	Vadose Zone Transport Field Studies	Reactive Transport Field Tests – 200 West Deep Sediments	The scope of this activity is to conduct integrated field-scale infiltration/reactive tracer experiments in the 200 West Area sediments at the same location as VZ-22. The outcome will be a documented set of field experiments and data sets for reactive transport in 200 West Area sediments that will be used for vadose zone parameter estimation, model verification, and history matching.	RL-SS30 – Understand and quantify movement in the vadose zone using uncontaminated field sites.	SAC, RPP Vadose Zone Project, Transport Modeling and Advanced Characterization, Field Investigations of Representative Sites S&T Activities, EMSP	SAC, Rev. 2, RPP Vadose Zone Project	Oct 01	Feb 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
VZ-25	Advanced Vadose Zone Characterization	Enhanced Methods for Plume Delineation at Tank Farm Surrogate Site in 200 East Area	The scope of this activity is to use advanced characterization technologies (e.g., tracers, advanced tensiometers, continuous soil water monitoring devices, cone penetrometer, electrical resistance tomography, high-resolution resistivity) to support the vadose zone transport field study tests in the 200 East Area vadose zone. The outcome will be a documented set of tests that describe the performance of enhanced characterization methods for moisture and contaminants.	RL-SS31 – Provide advanced characterization tools and methods to delineate contaminant plumes in the vadose zone and relate plume distributions to the distributions of geochemical and hydrogeological properties.	Vadose Zone Transport Field Study S&T Activity, Groundwater Project, RPP Vadose Zone Project, 200 Area Remedial Action Project, EMSP	VZ-22, RPP Vadose Zone Project, 200 Area Remedial Action Project	July 99	Sep 01
VZ-26	Advanced Vadose Zone Characterization	Enhanced Methods for Plume Delineation in 200 West Area Deep Sediments	The scope of this activity is to use advanced characterization technologies (e.g., tracers, advanced tensiometers, continuous soil water monitoring devices, cone penetrometer, electrical resistance tomography, high-resolution resistivity) to support the vadose zone transport field study tests in the 200 West Area vadose zone. The outcome will be a documented set of tests that describe the performance of enhanced characterization methods for moisture and contaminants.	RL-SS31 – Provide advanced characterization tools and methods to delineate contaminant plumes in the vadose zone and relate plume distributions to the distributions of geochemical and hydrogeological properties.	Vadose Zone Transport Field Study S&T Activity, Groundwater Project, RPP Vadose Zone Project, 200 Area Remedial Action Project, EMSP	VZ-23, VZ-24, RPP Vadose Zone Project, 200 Area Remedial Action Project	Oct 01	Feb 03
VZ-27	Advanced Vadose Zone Characteri-zation	Evaluation of Advanced Monitoring and Characterization Tools to Support SST Retrieval and Tank Closure Decisions	The scope of this activity is to evaluate tools with potential for monitoring contaminant plumes in the vadose zone of tank farms. The focus will be on identifying cost-effective methods for quantifying migration rates of mobile species such as Tc-99 and NO_3^-. The outcome will be a final report on the effectiveness of selected tools for detecting and delineating plumes of non-gamma-emitting species, such as Tc-99 and NO_3^- from which typical tank farm vadose zone migration rates can be inferred.	RL-SS31 – Provide advanced characterization tools and methods to delineate contaminant plumes in the vadose zone and relate plume distributions to the distributions of geochemical and hydrogeological properties.	Vadose Zone Transport Field Study S&T Activity, Groundwater Project, RPP Vadose Zone Project, EMSP	RPP Vadose Zone Project, VZ Final Report 1	Oct 01	May 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Groundwater Technical Element								
GW-1	GW/VZ Interface Study	Depth-Discrete Sampling at the GW/VZ Interface – Soil Disposal Sites	The scope of this activity is to evaluate the 3D plume structure in groundwater underlying and immediately downgradient of the waste site. Additional depth-discrete data will be collected in new and existing wells. The outcome will be direct evidence about the transfer and delivery of contaminants and water from the vadose zone to the groundwater. Alternative hypotheses are inferred by alternative near-source 3D plume structures.	RL-SS32 – Understand and quantify the relationship between contaminant sources, vadose zone plume properties, and groundwater plume properties at hydrologic boundaries, with a focus on the GW/VZ interface.	Groundwater Project (Lead), 200 Area Remedial Action Project, Field Investigations of Representative Sites, and Reconciliation of Model and Field Data S&T Activities	VZ-2, SAC, Rev. 1	Oct 00	Aug 01
GW-2	GW/VZ Interface Study	Depth-Discrete Sampling at Vadose Zone Discharge – WMA B-BX-BY	The scope of this activity is to evaluate a 3D plume at the discharge point from the vadose zone to the groundwater. Additional depth-discrete data will be collected from existing and new wells near dilute waste tanks. The outcome will be a documented evaluation of 3D groundwater plume development at B-BX-BY to support numerical transport modeling. Similar to GW-1, this activity will provide insight into the nature of transfer and delivery of contaminants from the vadose zone to the groundwater to support the RPP RFI.	RL-SS32 – Understand and quantify the relationship between contaminant sources, vadose zone plume properties, and groundwater plume properties at hydrologic boundaries, with a focus on the GW/VZ interface.	RPP Vadose Zone Project, Groundwater Project, Field Investigations of Representative Sites, and Reconciliation of Model and Field Data S&T Activities	VZ-3	Oct 01	Feb 02
GW-3	GW/VZ Interface Study	Depth-Discrete Sampling at Vadose Zone Discharge – Concentrated HLW Tank and Key 200 Area Soil Sites	The scope of this activity is to perform spatial and temporal interpretation of historical groundwater data to better evaluate 3D plumes at the vadose zone interface. Additional depth-discrete data will be collected from existing and new wells near concentrated waste tanks. The outcome will be a documented evaluation of 3D plume development at a HLW tank and key soil sites to support numerical transport modeling.	RL-SS32 – Understand and quantify the relationship between contaminant sources, vadose zone plume properties, and groundwater plume properties at hydrologic boundaries, with a focus on the GW/VZ interface.	Groundwater Project (Lead), RPP Vadose Zone Project, Groundwater Project, Field Investigations of Representative Site, and Reconciliation of Model and Field Data S&T Activities	VZ-4	Oct 01	Sep 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
GW-4	GW/VZ Interface Study	Tritium Plume Development	The scope of this activity is to evaluate development of a new tritium plume from the C018H facility to better define 3D flow. The outcome will be a documented conceptual model for C018H for testing numerical models.	RL-SS32 – Understand and quantify the relationship between contaminant sources, vadose zone plume properties, and groundwater plume properties at hydrologic boundaries, with a focus on the GW/VZ interface.	Groundwater Project (Lead), SAC	SAC, Rev. 3	Oct 03	Aug 04
GW-5	Biogeochemical Reactive Transport	Biogeochemical Transport of TRU in DNAPL	The scope of this activity is to develop a reactive transport model to determine the fate of plutonium, americium, and neptunium in DNAPL as mixture reaches groundwater. The outcome will be a documented reactive transport model of TRU and DNAPL in groundwater.	RL-SS34 – Understand, quantify, and develop descriptions of biogeochemical reactions and interactions between contaminants of concern and aquifer sediments to describe biochemical reactive transport.	200 Area Remedial Action Project, SAC, and Vadose Zone Transport Modeling S&T Activity	200 Area Remedial Action Project, SAC, Rev. 2	Feb 01	Feb 03
GW-6	Biogeochemical Reactive Transport	Biogeochemical Transport of TRU Discharged to Reverse Wells	The scope of this activity is to document factors controlling transport of radionuclides of concern (especially TRU elements such as neptunium) associated with bismuth phosphate process as they enter the unconfined aquifer. The outcome will be a documented reactive transport model of TRU discharged to reverse wells.	RL-SS34 – Understand, quantify, and develop descriptions of biogeochemical reactions and interactions between contaminants of concern and aquifer sediments to describe biochemical reactive transport.	SAC, 200 Area Remedial Action Project, and Vadose Zone Transport Modeling S&T Activity	SAC, Rev. 2	Feb 01	Feb 03
GW-7	Biogeochemical Reactive Transport	CCl4 Biochemistry	The scope of this activity is to develop an improved quantitative understanding of the distribution of DNAPL and CCl_4 and possible corrective actions. Specific goals include examinations of the CCl_4/DNAPL and the impact of disposal practices and modified wetting properties on vertical penetration and accumulation below the water table. The outcome will be documented multiphase reactive transport assessment of CCl_4.	RL-SS34 – Understand, quantify, and develop descriptions of biogeochemical reactions and interactions between contaminants of concern and aquifer sediments to describe biochemical reactive transport.	SAC, 200 Area Remedial Action Project, and Vadose Zone Transport Modeling S&T Activity	200 Area Remedial Action Project	Mar 02	Mar 04

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
GW-8	Hydrogeological Characterization Study	Historical Groundwater Data Review	The scope of this activity is to review and interpret historical data with the objective of addressing hierarchy of scales for hydrogeochemcial characterization. The outcome will be documented scaling studies to support groundwater characterization.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC and Groundwater Project	SAC, Rev. 1	Oct 00	Aug 01
GW-9	Hydrogeological Characterization Study	Multi-Scale Study – Soil Site	The scope of this activity is to conduct multiple-scale studies at a clean site, such as the ILAW or 200 Area Waste Sites Assessment site. The outcome will be documented scaling studies at soil sites.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC, RPP ILAW, 200 Area Remedial Action Project, Groundwater Project	SAC, Rev. 1 and GW-15	Oct 00	Aug 01
GW-10	Hydrogeological Characterization Study	Multi-Scale Study – Tank Site	The scope of this activity is to conduct multiple-scale studies at selected vadose representative tank site. The outcome will be documented scaling studies at a tank site.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC, RPP Vadose Zone Project, Groundwater Project, and Field Investigations of Representative Sites S&T Activity	SAC, Rev. 2 and GW-16	Feb 01	Feb 03
GW-11	Hydrogeological Characterization Study	Synthesis & Visualization of Hydrogeology – Soil Site	The scope of this activity is to refine existing field- and detailed-scale geological and hydrological maps used to build 3D computer visualization and input to numerical models; provide estimates of small-scale hydrological property variability and spatial correlation to numerical modeling; investigate scale dependence of hydraulic measurements; investigate important scales of physical and hydrological heterogeneity characterization; provide guidelines for modeling and monitoring; and develop suite of tools. The outcome will be documented synthesis and visualization of hydrogeologic data at a soil site.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	Groundwater Project, SAC, and 200 Area Remedial Action Project	GW-9	Oct 00	Aug 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
GW-12	Hydrogeological Characterization Study	Synthesis & Visualization of Hydrogeology – Tank Site	The scope of this activity is to refine existing field- and detailed-scale geological and hydrological maps to be used to build 3D computer visualization and input to numerical models; provide estimates of small-scale hydrological property variability and spatial correlation to numerical modeling; investigate scale dependence of hydraulic measurements; investigate important scales of physical and hydrological heterogeneity characterization; provide guidelines for modeling and monitoring; and develop suite of tools. The outcome will be documented synthesis and visualization of hydrogeologic data at a tank site.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	Groundwater Project, SAC, and RPP Vadose Zone Project	GW-10	Feb 01	Feb 03
GW-13	Regional Plume Geometry	3D Imaging of Regional Plumes	The scope of this activity is to define a transect, install wells, and collect depth-discrete sampling of groundwater extending from the 200 West Area to the river. The outcome will be documented 3D imaging of regional contaminant plumes.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC and Groundwater Project	SAC, Rev. 1	Oct 00	Aug 01
GW-14	Multi-scale 3D Model Development	Define 3D Modeling Objectives	The scope of this activity is to establish requirements for representation of continuum physics and chemistry across scale boundaries; balance localized geohydrological and biogeochemical environments at facies or smaller scales; and consider multicomponent speciation and mineral phase interaction and decay and transformation rates. The outcome will be documented methods for multi-scale model development.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC and Groundwater Project	GW-15	Oct 00	Feb 01

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
GW-15	Multi-scale 3D Model Development	Multi-Scale Model Approach for Region - Interim	The scope of this activity is to develop and implement an approach for multi-scale modeling over a regional area with a focus on soil site issues. The outcome will be a interim documented approach for multi-scale 3D model development.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC and Groundwater Project	SAC, Rev. 1	Oct 00	Aug 01
GW-16	Multi-scale 3D Model Development	Multi-Scale Model Approach for Region - Final	The scope of this activity is to develop and implement an approach for multi-scale modeling over a regional area with a focus on tank site issues. The outcome will be a final documented approach for multi-scale 3D model development.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC and Groundwater Monitoring Project	SAC, Rev. 2	Oct 01	Feb 03
GW-17	Multi-scale 3D Model Development	Site–Specific Multi-Scale 3D Model Development – WMA S-SX	The scope of this activity is to develop a method for incorporating heterogeneity and uncertainty in multi-scale modeling for a specific site leak below boiling waste tanks. Builds on field data being collected in S-SX WMA. The outcome will be a documented approach for site-specific 3D groundwater model development at WMA S-SX.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC, Groundwater Project, RPP Vadose Zone Project, and Field Investigations of Representative Sites S&T Activity	VZ-1	Oct 00	Feb 01
GW-18	Multi-scale 3D Model Development	Site–Specific Multi-Scale 3D Model Development – Specific Retention Basins	The scope of this activity is to develop and implement an approach for incorporating heterogeneity and uncertainty in multi-scale modeling for a specific site for 200-BP-1. The outcome will be a documented approach for site-specific 3D groundwater model development at 200-BP-1.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC, Groundwater Project, and Field Investigations of Representative Sites S&T Activity	VZ-2	Oct 00	Aug 01
GW-19	Multi-scale 3D Model Development	Site–Specific Multi-Scale 3D Model Development – WMA B-BX-BY	The scope of this activity is to develop and implement an approach for incorporating heterogeneity and uncertainty in multi-scale modeling for a specific site for leaks beneath dilute waste tanks. The outcome will be a documented approach for site-specific 3D groundwater model development at WMA B-BX-BY.	RL-SS33 – Techniques to delineate groundwater plumes in three dimensions, and define a scientific basis for addressing scaling issues in Hanford Site groundwater.	SAC, Groundwater Project, RPP Vadose Zone Project, and Field Investigations of Representative S&T Activity	VZ-3	Oct 01	Mar 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
GW-20	Ground-water Discharge Study	GW Discharge Study	The scope of this activity is to install, interpret, and image data from an array of multi-level samplers near the river, away from the bank storage area. The outcome will be documented 3D plume behavior near the river.	RL-SS35 – Technologies to quantify the flux of contaminant from Hanford Site groundwater to the Columbia River.	Groundwater Project (Lead) and River Technical Element	Groundwater Project and CR-15	Oct 00	Oct 01
Columbia River Technical Element								
CR-1	Detailed Conceptual Model	Rev. 1 Conceptual Model of River	The scope of this activity is to develop a detailed conceptual model of the river system. The activity includes critical processes and components necessary to conduct an acceptable river assessment and identifies links between activities across project. The conceptual model will provides the basis for prioritizing and coordinating related activities and enable S&T development and application in a meaningful manner. The outcome will be a documented conceptual model of the Columbia River.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead), River Monitoring Project, and Inventory Technical Element	SAC, Rev. 1 and River Monitoring Project	Mar 01	Sep 01
CR-2	Detailed Conceptual Model	Rev. 2 Conceptual Model of River	The scope of this activity is to update the river conceptual model based on additional field data and an update of scope and requirements from the SAC, Rev. 2. The outcome will be a documented conceptual model of the Columbia River.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead), River Monitoring Project, Inventory S&T Activity	SAC, Rev. 2 and River Monitoring Project	Dec 02	Apr 03
CR-3	Detailed Conceptual Model	Rev. 3 Conceptual Model of River	The scope of this activity is to update the river conceptual model based on additional field data and an update of requirements from the SAC, Rev. 3. The outcome will be a documented conceptual model of the Columbia River.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead), River Monitoring Project, Inventory S&T Activity	SAC, Rev. 3 and River Monitoring Project	Jun 04	Oct 04

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
CR-4	Information Management	Processes and Systems for River Data Management	The scope of this activity is to develop functional information management system. Define and implement the processes and establish the system necessary to gather, screen, manage, and disperse the data/information generated both inside and outside the Hanford Site domain that is considered in the river assessment. The outcome will be a documented, functional information management system.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead), Inventory Technical Element, River Monitoring Project	CR-1, CR-8, CR-12, CR-13, CR-18, and SAC, Rev. 1	Mar 01	Sep 01
CR-5	Information Management	Data Mining and Input Data to SAC, Rev. 1	The scope of this activity is to review available data from multiple agencies and include those data that support review and update of the conceptual model into the information system. Provide data for the SAC, Rev. 1. The outcome will be a documented, functional information management system.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead), and River Monitoring Project	CR-1, CR-15, and SAC, Rev. 1	Jun 01	Sep 01
CR-6	Information Management	Update Information System, Rev. 2 of SAC	The scope of this activity is to update the information management system for SAC, Rev. 2. The outcome will be a documented, functional information management system.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead) and River Monitoring Project	CR-2, CR-16, and SAC, Rev. 2	Dec 02	Apr 03
CR-7	Information Management	Update Information System, Rev. 3 of SAC	The scope of this activity is to update the information management system for SAC, Rev. 3. The outcome will be a documented, functional information management system.	RL-2236 – Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.	SAC (Lead) and River Monitoring Project	CR-3, CR-17, and SAC, Rev. 3	Jun 04	Oct 04

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
CR-8	Characterization	Fate and Transport Model Parameterization	The scope of this activity is to determine biological transfer factors for contaminant/species combinations of interest. The outcome will be a documented set of parameters to be used in development of biological transport model.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC and River Monitoring Project (Joint Leads)	SAC, Rev. 1	Oct 00	Oct 01
CR-9	Characterization	Environmental Data Collection-Transport and Fate for SAC, Rev. 1	The scope of this activity is to identify sensitive habitats and critical locations, define species abundance and distribution within study domain, and obtain environmental data required to develop and validate conceptual, fate, and transport models. The outcome will be documented data for physical transport and fate models to support SAC, Rev. 1.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC and River Monitoring Project (Joint Leads), Ecological Risk Assessment S&T Activity	SAC, Rev. 1, CR-15, and River Monitoring Project	Oct 00	Oct 01
CR-10	Characterization	Environmental Data Collection-Transport and Fate for SAC, Rev. 2	The scope of this activity is to update sensitive habitat and critical locations as needed for SAC, update species abundance and distribution information, and update the contaminant database. The outcome will be documented data for physical transport and fate models to support SAC, Rev. 2.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC and River Monitoring Project (Joint Leads), Ecological Risk Assessment S&T Activity, and River Monitoring Project	SAC, Rev. 2, CR-16, and River Monitoring Project	Oct 01	Apr 03
CR-11	Characterization	Environmental Data Collection-Transport and Fate for SAC, Rev. 3	The scope of this activity is to update sensitive habitat and critical locations as needed for SAC, update species abundance and distribution information, and update the contaminant database. The outcome will be documented data for physical transport and fate models to support SAC, Rev. 3.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC and River Monitoring Project (Joint Leads), Ecological Risk Assessment S&T Activity, and River Monitoring Project	SAC, Rev. 3, CR-17, and River Monitoring Project	May 03	Oct 04

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
CR-12	Groundwater – River Interface Study	Define Groundwater Dynamics and Simulation	The scope of this activity is to develop site-specific conceptual model(s) consistent with the requirements of the SAC River Technical Element. The outcome will be documented conceptual model of groundwater/river dynamics.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, and SAC	SAC, Rev. 0	Oct 99	Sep 00
CR-13	Groundwater – River Interface Study	Trend Evaluation of Discharges	The scope of this activity is to understand the dynamics of flow direction, attenuation, decay, chemical transformation, biological processes, transport rates, and preferential pathways associated with contaminant discharge from aquifer into the river by conducting field and complementary lab experiments to fill data needs relative to these physical, chemical, and biological processes. The outcome will be documented laboratory and field experiments to investigate groundwater/river dynamics.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, and SAC	SAC, Rev. 0 and CR-14	Oct 00	May 01
CR-14	Groundwater – River Interface Study	Numerical Models for Groundwater Discharge to River	The scope of this activity is to develop numerical model of groundwater/river interactions to support linking the spatial scales of the groundwater model outputs with those necessary in ecological assessments and providing contaminant flux into the river. The outcome will be documented numerical models of groundwater/river dynamics.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, and SAC	SAC, Rev. 0	Oct 99	May 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
CR-15	Groundwater – River Interface Study	Evaluate Predictive and Observational Data, Rev. 1	The scope of this activity is to evaluate predictive and observational data against impact criteria and evaluate trends in predictive and observational data of changing conditions in the groundwater/ river interface. The outcome will be a documented evaluation of the predictive models for the groundwater/river interface.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, Risk S&T Technical Element, and SAC	SAC, Rev. 1	Oct 00	Oct 01
CR-16	Groundwater – River Interface Study	Evaluate Predictive and Observational Data, Rev. 2	The scope of this activity is to evaluate predictive and observational data against impact criteria and evaluate trends in predictive and observational data indicative of changing conditions in the groundwater/river interface. The outcome will be a documented evaluation of the predictive models for the groundwater/river interface.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, Risk S&T Technical Element, and SAC	SAC, Rev. 2	Sep 02	Apr 03
CR-17	Groundwater – River Interface Study	Evaluate Predictive and Observational Data, Rev. 3	The scope of this activity is to evaluate predictive and observational data against impact criteria and evaluate trends in predictive and observational data indicative of changing conditions in groundwater/river interface. The outcome will be a documented evaluation of the predictive models for the groundwater/river interface.	RL-SS37 – Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.	River Monitoring Project, Groundwater Project, Risk S&T Technical Element, and SAC	SAC, Rev. 3	Oct 03	Oct 04
CR-18	Fate and Transport	Analytical Models for River Transport and Fate	The scope of this activity is to develop a detailed quantitative conceptual model of the river system based on analytical models, existing data, and limited application of numerical models. The outcome will be documented conceptual models for the river system.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC Project (Lead) and River Monitoring Project	SAC, Rev. 0, R-19, R-20, and R-21	May 99	Sep 00

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
CR-19	Fate and Transport	Hydrodynamic Model for River System	The scope of this activity is to develop and apply hydrodynamic models to describe and predict contaminant migration and fate in the river environment. These models will be evaluated against measurements and monitoring data for the river. The outcome will be documented hydrodynamic models of the Columbia River.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC Project (Lead) and River Monitoring Project	SAC, Rev. 2 and CR-20, CR-21	Oct 01	Apr 03
CR-20	Fate and Transport	Sediment and Biological Transport Models for River	The scope of this activity is to develop and apply numerical models of sediment transport, especially in the groundwater/ river interface, to support estimation of concentrations of contaminants available to organisms in this region to complement biological transfer and toxicological studies. Using these transfer rates, numerical models of the biological transport will be developed. These models will be evaluated against measurements and monitoring data for the river. The outcome will be a documented numerical model of sediment and biological transport in the river.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC Project (Lead) and River Monitoring Project, Ecological Risk S&T Activity	SAC, Rev. 2 and CR-21	Oct 01	Apr 03
CR-21	Fate and Transport	Contaminant Transport Model for River	The scope of this activity is to develop and apply contaminant transport models by assembling hydrodynamic, sediment, and biological transport models for the river to support risk assessment activities within the SAC. Depends on outcomes from CR-19 and CR-20. These models will be evaluated against measurements for the river. The outcome will be a documented numerical model of contaminant transport in the river.	RL-SS38 – Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.	SAC Project (Lead) and River Monitoring Project	SAC, Rev. 2	Oct 01	Apr 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Risk Technical Element								
R-1	General Risk Assessment	Stakeholder Identification and Consensus	The scope of this activity is to develop methods to identify, involve, and build consensus among stakeholders for determining areas of focus for the risk technical element. Specifically, methods for defining endpoints, resources of concern, and impact thresholds that will guide the risk assessment process and focus S&T activities for risk. This stakeholder group must extend beyond those required by law to be involved. The outcome will be a report documenting the methodologies developed, and provide recommendations for activities to be pursued by characterization, SAC, and S&T.	TBD	SAC, 200 Area Remedial Action Project, Public Safety and Resource Protection Project, Economic, Human Health, and Socio-Cultural Risk S&T Activities	SAC, Rev. 2	Oct 01	Sep 02
R-2	Ecological Risk Assessment	Continuous Toxicological Response	The scope of this activity is to quantify toxicological response profiles for selected Hanford Site contaminants and representative species of concern. Studies are needed to improve the accuracy of predicted toxicological responses and move away from the gross “acute versus chronic” categorization of exposure duration. The contaminants and species to be studied will be determined through interactions with the SAC development team. The outcome will be a database of survival times or proportional hazards as a function of concentration and duration of exposure for representative species and selected contaminants.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-3	Ecological Risk Assessment	Extrapolations Across End Points	The scope of this activity is to modify current approaches for extrapolating individual responses to population- and community-level responses (e.g., primary production, population growth rates). Alternatives will be tested using laboratory or other controlled studies, and evaluate if effects of contaminants aggregated across higher levels of organization are additive. The outcome will be documented extrapolation methods and a database of parameterized endpoint extrapolations for selected contaminants and representative species.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 2	Oct 00	Mar 02
R-4	Ecological Risk Assessment	Data for Higher Level Measurement End Points	The scope of this activity is to develop dose-response data for selected receptors (attributes) above the level of the individual. The preferred endpoints include population and community metrics. This will rely on laboratory studies to expand the applicability to R-2. The outcome will be a report on dose responses for selected contaminants and representative population/community-level endpoints.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 2	Oct 00	Mar 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-5	Ecological Risk Assessment	Development of Risk Integration Methods	The scope of this activity is to conduct research on the utility of augmenting the weight-of-evidence approach to integrating diverse impact metrics with Bayesian methods to improve accuracy of ecological risk assessments and reduce process-based uncertainty. This activity is critical in the final phase of an ecological risk assessment where the results of exposure and response models are integrated. The outcome will be a report documenting ecological risk integration methods, their relative strengths and weaknesses, and recommendations for use at the Hanford Site.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 2	Oct 01	Mar 03
R-6	Ecological Risk Assessment	Compensatory Uptake Across Multiple Exposure Pathways	The scope of this activity is to quantify the changes in uptake (absorption) factors of gut versus gill (or lung) versus dermis when concentrations in one exposure medium are varied independently of other media. This will be used to reduce uncertainties in multimedia contaminant uptake models. The outcome will be a set of functions for multimedia contaminant uptake for selected species and contaminants.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03
R-7	Ecological Risk Assessment	Exposure Scenarios for Specific Groups	The scope of this activity is to develop exposure scenarios for selected organisms that are exposed to multiple media. These may include benthic invertebrates (exposure to pore water vs. river water) and riparian plants (exposure to groundwater, soil, and meteoric water). The outcome will be quantitative models of fractional exposures to selected contaminants through multiple media for selected organisms.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, Groundwater – River Interface Study S&T Activity	SAC, Rev. 2	Oct 00	Mar 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-8	Ecological Risk Assessment	Modifiers to Exposure	The scope of this activity will be to quantify the bioavailability of selected Hanford Site contaminants to representative Columbia River species (riparian and aquatic). This may include examination of root exudates on plant uptake from soils and groundwater, effects of complexants on gut and gill absorption, effects of dietary sorbants on gut absorption, metal speciation and complexation effects on gill and dermal absorption, etc. The outcome will be a documented database of bioavailability for selected contaminants and representative Columbia River species under likely environmental conditions.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03
R-9	Ecological Risk Assessment	Pathway Integration	The scope of this activity is to assess the uptake and effects of selected Hanford Site contaminants relative to various pathways of exposure for representative species. This may include literature reviews and laboratory studies where data gaps exist. The outcome will be documented relative response functions for selected contaminants and representative species with respect to different exposure pathways.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03
R-10	Ecological Risk Assessment	Toxicity by Mode of Action	The scope of this activity is to define and quantify mode of action and target organ toxicity for selected contaminants and representative species. This may include literature reviews, but will also require laboratory toxicity studies. The outcome will be a documented database of modes of action and target organ toxicity for selected contaminants and representative species.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-11	Ecological Risk Assessment	Extrapolations Across Taxa	The scope of this activity is to conduct studies of the efficacy and utility of response extrapolation methods for representative species and selected contaminants. This may include literature searches as well as laboratory studies. The outcome will be a documented evaluation of the alternatives and the necessary data to perform extrapolations for selected contaminants and representative species.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03
R-12	Ecological Risk Assessment	Adaptive Responses	The scope of this activity is to conduct toxicokinetic-toxicodynamic research on selected Hanford Site contaminants and representative species sufficient to predict toxicity of a time-varying exposure to contaminants in one or more media. This research may include multiple compartments where contaminants accumulate in specific organs, and food-chain studies that will document the relative absorption, excretion, metabolism, and toxicity of selected Hanford Site contaminants as a function of the physicochemical forms that the contaminants may be delivered via the food chain. The outcome will be a documented series of parameterized toxicokinetic-toxicodynamic models for selected contaminants and representative species.	TBD	SAC, Public Safety and Resource Protection Project, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project	SAC, Rev. 3	Oct 00	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-13	Economic Risk Assessment	Risk Perception and Trigger Mechanisms	The scope of this activity is to develop methods for predicting how residents, recreationists, consumers of agricultural products, and other stakeholder groups process and respond to information concerning risks posed by environmental contamination. Several controlled survey-based studies will be done of different groups. The outcome will be a documented set of methods to predict economic impacts of environmental contamination.	TBD	SAC and Socio-Cultural Risk Assessment S&T Activity	SAC, Rev. 3	Oct 00	Sep 03
R-14	Economic Risk Assessment	Recreational Impacts	The scope of this activity is to provide baseline data on Columbia-River-based recreation and value necessary to calibrate economic and human health models. Data on the level, location, and type of recreational activities are needed to establish how individuals using the Columbia River for recreation could be exposed to Hanford Site contaminants. These data are necessary to estimate the direct economic value of the activity to the participants and to estimate the impact of changes in the level of contamination. The outcome will be a documented database of recreational activities on the Columbia River and the value of that activity to participants.	TBD	SAC	SAC, Rev. 2	Oct 00	Sep 02
R-15	Economic Risk Assessment	Preference Ordering of Non-Market Resources	The scope of this activity is to develop a process-oriented method for evaluating competing preferences for alternative ecological scenarios. A decision analytic approach will be used to identify the values relevant to evaluating the alternatives. The product will be a documented method for evaluating choice between alternative ecological scenarios.	TBD	SAC and Ecological Risk Assessment S&T Activity	SAC, Rev. 2	Oct 01	Sep 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-16	Economic Risk Assessment	Benefit Transfer	The scope of this activity is to improve methods for employing benefits transfer methods to estimate non-market responses to environmental hazards. Benefit transfer is generally seen as an efficient, cost-effective method for developing estimates of the economic benefit associated with specific natural resources. The outcome will be documented procedures and criteria for transferring benefit estimates from one geographic location and circumstances to another.	TBD	SAC	SAC, Rev. 2	Oct 01	Mar 03
R-17	Economic Risk Assessment	Mobility of Local Residents	The scope of this activity is to determine the mobility patterns of local residents in response to potential exposures to Hanford Site contaminants and resulting changes in economy. The migration patterns will be evaluated with historical studies and surveys of residents to determine propensities to migrate and gross migration flows for existing residents in the region in response to Hanford Site contaminants and other indirect economic stimuli (e.g., responses to net job gains and losses). The outcome will be a documented model of resident migration behavior around the Hanford Site.	TBD	SAC and Human Health Risk Assessment S&T Activity	SAC, Rev. 2	Oct 01	Sep 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-18	Human Health Risk Assessment	Biomarkers of Exposure	The scope of this activity is to develop reliable biophysical measurement methods to provide quantitative indications of individual exposures to selected Hanford Site contaminants. Studies are needed to identify applicable markers, develop methods to quantitatively measure these markers, and evaluate their applicability for extrapolating to diverse populations. The outcome will be documented clinical methods for determining exposures to selected Hanford Site contaminants.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project	SAC, Rev. 3, RPP Vadose Zone Project	Oct 00	Sep 03
R-19	Human Health Risk Assessment	Toxicokinetics-Toxicodynamics of Mixtures	The scope of this study is to develop methods for incorporating the toxicokinetic response to mixtures of chemicals. Improved data on biological responses to mixtures are needed for risk assessments. The outcome will be documented models for describing the fate of mixtures and associated responses in the human body.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project, Groundwater Project	SAC, Rev. 3, RPP Vadose Zone Project	Oct 00	Sep 03
R-20	Human Health Risk Assessment	Toxicokinetics and Toxicodynamics of Active Agents and Their Distribution in the Body	The scope of this activity is to develop parameters for incorporating toxicokinetic and toxicodynamic models into exposure assessments. This will include consideration of homeostasis. Improved information on absorption of material into the body and additional knowledge of the effects of intermediate degradation products are needed to improve exposure assessment. The outcome will be documented models of the fate of selected Hanford Site contaminants in the body.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project	SAC, Rev. 3, RPP Vadose Zone Project	Oct 00	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-21	Human Health Risk Assessment	Contaminant Bioavailability in the Environment	The scope of this activity is to determine the role of speciation, absorption, complexation, and other environmental factors in availability of selected contaminants for human uptake. The transformation of chemical compounds, chemical speciation, and environmental consideration impacts on human uptake will be studied. The outcome will be a database of bioavailabilities of selected Hanford Site contaminants under likely environmental conditions.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project, and Ecological Risk Assessment S&T Activity	SAC, Rev. 3, RPP Vadose Zone Project	Oct 00	Sep 03
R-22	Human Health Risk Assessment	Cancer Endpoints	The scope of this activity is to develop the distributions for cancer slope factors for selected Hanford Site contaminants using existing scientific data. The outcome will be a matrix of the probability distributions for slope factors of selected Hanford Site contaminants, with descriptive information on modes of action.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project	SAC, Rev. 2, RPP Vadose Zone Project	Oct 00	Sep 02
R-23	Human Health Risk Assessment	Multiple End Points	The scope of this activity is to develop methods to represent multiple human health impacts. These include the possibility of mutagenic, teratogenic, and developmental changes; reproductive effects (including reduced birth rates and weights); neurological, immunological, and metabolic effects; and/or behavior effects. While data are available for selected health endpoints for some contaminants of interest, much of the existing information needs to be validated through additional laboratory analyses or alternative modeling methods. The outcome will be a documented set of methods for representing a range of endpoints beyond the limiting effects.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project	SAC, Rev. 3, RPP Vadose Zone Project	Oct 00	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-24	Human Health Risk Assessment	Food Chain Transfer Factors	The scope of this activity is to develop transfer factors that link biological or abiotic concentrations of selected Hanford Site contaminants to bioavailability specific to human intake. This will involve synthesizing existing data as well as research on non-agricultural products used by Native Americans. The focus will be on how food processing (cooking, pickling, drying, etc.) impacts the concentrations of contaminants in food products. The outcome will be a documented database of food chain transfer factors.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project; Ecological Risk Assessment S&T Activity	SAC, Rev. 3, RPP Vadose Zone Project	Oct 01	Sep 03
R-25	Human Health Risk Assessment	Exposure Pathways	The scope of this activity is to develop exposure scenarios unique to the Hanford Site (e.g., Native American and other groups such as migrant workers). This will include determining ranges of exposure parameters to account for variability and the existence of non-standard routes of exposure (e.g., uses of indigenous materials) and the parameters associated with use. The outcome will be a documented set of exposure scenarios with parameters applicable to Hanford Site conditions.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project, Socio-Cultural Risk Assessment S&T Activity	SAC, Rev. 3, RPP Vadose Zone Project	Oct 01	Sep 03
R-26	Human Health Risk Assessment	Spatio-Temporal Variation in Amount of Exposure	The scope of this activity is to develop an understanding of temporal and spatial variations in human health exposure. Currently, intake and exposure are integrated and compared to steady-state benchmarks. The outcome will be a documented method to account for time-varying exposures.	TBD	SAC, 200 Area Remedial Action Project, 100/300 Area Remedial Action Project, RPP Vadose Zone Project	SAC, Rev. 3, RPP Vadose Zone Project	Oct 02	Sep 03

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
R-27	Socio-Cultural Risk Assessment	Modeling Risk Knowledge	The scope of this activity is to develop a risk perception model for groups affected by Hanford Site contaminants. The outcome will be a documented risk perception model useful for SAC.	TBD	SAC	SAC, Rev. 3	Oct 01	Sep 02
Monitoring Technical Element								
M-1	Identification, Development, and Deployment of Improved Environmental Monitoring	Improved Technical Basis for Environmental Monitoring	The scope of this activity is to develop and investigate technologies and strategies for environmental monitoring and multiple media.	TBD	Public Safety and Resource Protection Project, Groundwater Project	Hanford Environmental Monitoring	TBD	TBD
Remediation Technical Element								
Rem-1	Identification, Development, and Deployment of Improved Groundwater Remediation Strategies	Improved Technical Basis for Remediation of 200 West CCl4	The scope of this activity is to investigate the distribution of DNAPL (CCl_4) and assist with development of a strategy for corrective actions. This activity will include geophysical and geochemical S&T (e.g., surveys, tracer tests, microbial studies) as well as linkages to OST programs for remediation technology selection and deployment. This work will require improved reactive transport models. The outcome will be improved understanding of DNAPL behavior at Hanford and linkages of this information to solutions to meet specific regulatory goals.	RL-SS01 – Cost-Effective, In Situ Remediation of Carbon Tetrachloride in the Vadose Zone and Groundwater	Hanford Environmental Restoration, OST	Hanford Environmental Restoration	Jul 99	Jul 02

Table 4-1. S&T Schedule and Products for Inventory, Vadose Zone, Groundwater, and River Technical Elements. (41 Pages)

Id No.	S&T Activity	Descriptive Title	Brief Scope and Outcome	Responds to Need No. and Title	Interacts With	Product To	Desired Start Date of S&T Activity	Product Delivery Date
Rem-2	Identification, Development, and Deployment of Improved Groundwater Remediation Strategies	Improved Technical Basis for Remediation of 100 Area Plumes	The scope of this activity is to investigate contaminant plumes in the 100 Areas and assist with development of strategies for corrective actions – particularly for chromium (VI), Sr-90, tritium, and related constituents. This activity will include geophysical and geochemical S&T as well as linkages to OST programs for remediation technology selection and deployment. The outcome will be improved understanding of contaminant behavior and linkages of this information to solutions to meet specific regulatory goals.	RL-SS07 – Cost-Effective, In Situ Remediation of Strontium-90 in Groundwater	Hanford Environmental Restoration, OST	Hanford Environmental Restoration	Jul 99	Jul 02

CCl_4 = carbon tetrachloride
HLW = high-level waste
PUREX = Plutonium/Uranium Extraction Plant
RFI = RCRA facility investigation
ROD = Record of Decision
SST = single-shell tank
TBD = to be determined

5.0 BUDGET SUMMARY

The budget for the S&T activities proposed for the next 5 years is provided in Table 5-1. These estimates were based on the envisioned scope and past experience with costs for similar science and technology activities. Both site funding and leveraged funding from National S&T Programs are sought. Consequently, the budget for each S&T activity was split between site-provided funding (which was developed based on DOE guidance) and potential leveraged funding being sought by the Integration Project. The leveraged funding is identified by footnote in Table 5-1, and is not included in the budget total. In addition, some of the S&T tasks are being supported directly by core projects that will use the outcomes. Those tasks have been identified through footnotes in Table 5-1, and correspond to the S&T outcomes (shown in red) in Figure 4-1. A budget for project-led S&T activities is not included in the total budget. Finally, there are S&T activities that were conducted in FY99 and are being conducted in FY00. These activities are identified in Table 5-1, and budgets provided directly by the Integration Project are shown. All budget estimates will be refined subsequent to detailed FY01 planning, and prioritized as described in Section 6.0.

Table 5-1. Budget Summary by S&T Activity. (2 Pages)

Technical Element	S&T Activity	Potential FY99 Funding Program	FY99 ($K)	FY00 ($K)	FY01 ($K)	FY02 ($K)	FY03 ($K)	FY04 ($K)
Inventory	Unplanned Releases	Hanford	[b]	[b]				
	Soil Site Waste Inv	Hanford	130	190	390			
	Models for Sel. Cont.	Hanford		190				
	Release Models	Hanford		30[i]	130			
	River Source Term	Hanford			195[i]			
	Reconciliation of Model to Field Data	Hanford			130	130	130	
	Totals:		**130**	**410**	**845**	**130**	**130**	**0**
Vadose Zone	Field Investigations of Representative Sites	Hanford and EM-50[a]		1,330[c] 350[e]	1,500 500[e]	2,000 750[e]	2,000	1,000
	Transport Modeling	EM-50[a]		340 200[e]	1,000 200[e]	1,000 200[e]	1,000	500
	Waste-Sediment Lab Expts & Process Models	Hanford and EM-50[a]		[c]3500[e]	1,000 3000[e]	1,000 1500[e]	1,000	500
	Vadose Zone Transport Field Studies	Hanford and EM-50[a]	120	1,500 1,400[e]	1,500 1,300[e]	2,000 1,200[e]	2,000	1,000
	Advanced Vadose Zone Characterization	Hanford and EM-50[a]		1,700[e]	500 1,600[e]	500 400[e]	500	
	Totals:		**120**	**3,170**	**5,500**	**6,500**	**6,500**	**3,000**
Groundwater	Vadose Zone/Groundwater Interface Study	Hanford and EM-50[d]		100	650	300	300	
	Vadose Zone/Groundwater Interface Study – C018H	Hanford					750	
	Biogeochemical Reactive Transport - DNAPL/TRU	EM-50[d]			1,500	1,500		
	Biogeochemical Reactive Transport – Reverse Wells	EM-50[d]			1,500	1,500		
	Biogeochemical Reactive Transport – CCl4	EM-50[d]				600	600	600
	Hydrogeological Characterization - Scale Hierarchy	EM-50[d]			550	1,000	1,000	
	Hydrogeological Characterization – Synthesis/Visualization	EM-50[d]			150	150	150	
	Regional Plume Study	Hanford			2,100			
	Multi-scale 3-D Model Development - Regional	Hanford			150	250	250	

Table 5-1. Budget Summary by S&T Activity. (2 Pages)

Technical Element	S&T Activity	Potential FY99 Funding Program	FY99 ($K)	FY00 ($K)	FY01 ($K)	FY02 ($K)	FY03 ($K)	FY04 ($K)
Groundwater (cont.)	Multi-scale 3-D Model Development – Site-Specific	Hanford			150	500		
	Groundwater Discharge Study	Hanford	[h]					
		Totals:	**0**	**0**	**450**	**900**	**400**	
River	Detailed Conceptual Model	Hanford	[k]	[k]	175[l]	50[l]		
	Information Mgmt	Hanford			250[l]	75[l]		
	Characterization	Hanford		[k]	2,020[j]	500[j]	500[j]	500[j]
	Groundwater/River Interface Study	Hanford and EM-50[a]	[k]	250	500 500[d]	250	250	250
	Fate and Transport	Hanford and EM-50[a]	[k]	[k]	500	1,000	500	100
		Totals:	**0**	**250**	**1,000**	**1,250**	**750**	
Risk	General Risk Assessment	Hanford			150			
	Ecological Risk Assessment	Hanford and Other[d]			2,100 900[d]	2,400 1,600[d]	1,700 1,200[d]	
	Human Health Risk Assessment	Hanford and Other [d]			1,000 2,000[d]	1,400 1,700[d]	1,600 1,200[d]	
	Economic Risk Assessment	Hanford and Other [d]			500	1500 600[d]	500 200 [d]	
	Socio-Cultural Risk Assessment	Other [d]				600 [d]		
		Totals:	**0**	**0**	**3,750**	**5,300**	**3,800**	
Remediation	FY99 EMSP Awards	EM-50[e]		2,300[e]	2,200[e]	800[e]		
Monitoring	FY99 EMSP Awards	EM-50[e]		800 [e]	1,000 [e]	800 [e]		
S&T Roadmap[m]			**900**	**900**	**500**	**500**	**500**	
Grand Total			**1,150**	**4,700**	**11,350**			

[a]Funding to be requested/negotiated with the OST (EM-50).
[b]RPP provided funding for Tc mass balance studies and leak losses from thermally hot tanks in FY99.
[c]Scope will include key waste-sediment laboratory experiments needed to complement development of conceptual models and field data collection and analysis.
[d]Identified as appropriate for national S&T funding; the Integration Project will seek leveraged funding from national S&T programs for scope associated with this portion of the budget.
[e]Potentially relevant work being conducted in the ongoing EMSP from the FY99 call.
[f]Selected advanced characterization scope will be planned initially in the Vadose Zone Transport Field Study Site activity.
[g]The Integration Project will leverage ongoing EM-50 and planned core project work to deploy advanced characterization tools.
[h]River Monitoring Project has the lead and have initiated field studies.
[i]SAC has lead for these tasks; no funding is assumed for S&T.
[j]River Monitoring Project has the lead for this task; no funding is assumed for S&T.
[k]SAC has initiated development of conceptual models for the river and groundwater/river interface.
[l]Characterization of systems has the lead for these tasks; no funding is assumed for S&T.
[m]Roadmap task includes interfaces with National S&T Programs and end users, as well as updating the roadmap for additional technical elements (e.g., remediation and monitoring).

6.0 S&T PRIORITIES FOR FY01

The main objective of prioritizing project activities is to ensure that investments are made in activities that have the greatest potential for improving site decisions. A project activity therefore derives its basic priority from two fundamental considerations: 1) the relative importance of the decisions it is intended to affect; and 2) the anticipated impact it will have on those decisions. S&T activities derive their priority from their ability to improve the technical basis for key decisions identified as a priority by the Integration Project. Scheduling, cost, and budget characteristics further determine whether (and how) an activity is supported in a given year.

To prepare for FY00 detailed work planning, a prioritization process was conducted involving S&T leads, core project and Integration Project staff and RL. The project established priorities based on their value for addressing uncertainties inherent in the site's ability to perform defensible assessments of the cumulative effects of its wastes. Specifically, the ability to improve scientific and technical credibility for remediation and closure decisions (from both a site-wide and site-specific perspective) was considered by participants in the prioritization process. The approach taken to conduct a prioritization included the following steps:

- S&T outcomes from this roadmap were rank ordered and then rated for importance within each technical element by a collection of S&T leads and core project managers (both DOE and contractor) for the SAC, RPP Vadose Zone Project, and 200 Area Remedial Action Project.

- The four technical areas (inventory, vadose zone, groundwater, and river) were then rank ordered and rated for their importance by the core project managers.

- A simple algorithm was subsequently used to globally weight and order the S&T outcomes.

- The raw ordering was then aligned with timing (length of time to conduct science) and opportunities (schedules for field activities through the core projects) to develop the final prioritized list for S&T outcomes.

Using this logic and approach, priorities were established for S&T outcomes identified in Table 4-1 and associated budgets in Table 5-1. The priorities were established for each technical element as:

- Inventory Technical Element: Methodologies are needed immediately for estimating inventories for soil waste sites for which historical records and characterization data are not adequate. Methodologies are also needed to describe the uncertainty in our knowledge of those data, and to reflect a total mass balance (rather than conservative assumptions) in order to support the SAC.

- Vadose Zone Technical Element: This technical element was rated as high as inventory because of the need for improved understanding of the processes controlling fate and transport of contaminants in the vadose zone. This need is important over the next 3 to 5 years, and the opportunities to leverage planned field activities exist over the next 1 to 3 years. There was a bias toward data collection from both contaminated, representative field sites, and an uncontaminated site. Both laboratory experiments and numerical modeling were considered important to support the field activities.

- River and Groundwater Technical Elements: The river and groundwater technical elements were each rated equally (and lower) than the inventory and vadose zone technical elements. The Hanford Site's understanding of the groundwater is more mature than that of the vadose zone, and additional investments will be guided by very specific needs of the SAC as it sets requirements for dealing with heterogeneity and uncertainty issues, and by the needs of specific remediation activities in the near future. Within the river technical element, there was a bias towards better understanding the dynamics of the river bank region and biological transfer of contaminants.

These priorities (documented in Rev. 0 of this document) formed the basis for detailed work plans developed by the Integration Project for FY00 funding.

For FY01 planning, the Integration Project will maintain these priorities, adding work on the risk technical element that is focused on the ecological component. Initial priorities established during and Integration Project workshop focused on developing detailed work plans for 2001 pointed to an outcome of being able to address the impacts of cesium and strontium on the ecological resources of the Columbia River within the next three years. The initial investments in the risk assessment element will focus on biological transfer of these contaminants in Columbia River species. Specific budgets for FY01 will be established during the detailed work planning process.

7.0 REFERENCES

DOE-RL, 1998, *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1999, *200-BP-1 Prototype Barrier Treatability Test Report*, DOE/RL-99-11, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

References

APPENDIX A

INTEGRATED S&T TO SUPPORT REMEDIATION

APPENDIX A

INTEGRATED S&T TO SUPPORT REMEDIATION

Science and Technology (S&T) activities are being done by core projects and national programs to support the following Hanford Site remediation projects:

- Groundwater Remediation
- 100/300 Area Waste Sites
- River Protection Program Vadose Zone (Corrective Measures)
- 200 Area Remedial Action.

Groundwater Remediation and Hanford Burial Grounds/Waste Sites: Pump-and-treat methods for groundwater remediation are currently being used to remediate the river (e.g., 100-D, 100-H, 100-N, and 100-K Areas) and plateau sites (e.g., 200-UP-1 and 200-ZP-1 Operable Units). Alternative groundwater treatments are being considered for the 100-H and 100-K Areas and the 200-ZP-1 Operable Unit through field-scale feasibility studies. Additionally, various soil and burial ground remedial activities are underway or planned within the next 5 years (100/200/ 300 Areas). Decisions for alternative treatment are scheduled (as shown below). The planned S&T activities for these feasibility studies include the following:

- **Burial Ground Remediation (100 Area)** - Currently, 45 burial grounds are scheduled for excavation. The final design for the excavations will specify technologies for excavation, characterization, segregation, and treatment, where necessary. Insertion Point Milestone: FY01.

- **Soils and Burial Ground Remediation (200 Area)** - Planning is underway for the 200 Area soils and burial grounds. Assessment of potential remedial action alternatives will consider technologies for excavation, capping, characterization, segregation, and treatment, where necessary. Insertion Point Milestone: FY01.

- **300-FF-2 Remediation (300 Area)** - Planning is underway for the 300-FF-2 Operable Unit soils and burial grounds. Assessment of potential remedial action alternatives will consider technologies for excavation, capping, characterization, segregation, and treatment, where necessary. Insertion Point Milestone: FY06.

- **Chromium Remediation (100 Area Groundwater)** - The current interim remedial measure (IRM) for the chromium plumes is pump and treat (to contain the plume such that chromium does not migrate into the Columbia River). An alternative treatment option through application of in situ remediation technology is currently being deployed, and improved pump-and-treat approaches are being considered. The pump-and-treat approach is expensive and in situ redox may have limited application; other alternatives for a permanent final remediation for all the chromium plumes will be considered. Insertion Point Milestone: FY02.

- **Carbon Tetrachloride Remediation (200 Area Groundwater)** - The current interim remedial measure for the carbon tetrachloride plume is pump and treat, to contain the plume within the 2,000- to 3,000-µg/L contour boundaries. The current approach would need to be expanded significantly and continued for several years to treat the entire plume. Enhanced treatment through application of in situ remediation techniques (or improved pump-and-treat approaches) are being considered as ways to speed remediation and reduce costs. Insertion Point Milestone: FY01.

- **Strontium Remediation (100 Area Groundwater)** - The current remedial action for the strontium plume is pump and treat, to contain the plume such that strontium does not migrate into the Columbia River. Enhanced treatment through application of in situ remediation techniques or improved pump-and-treat approaches are being considered. The current approach is expensive, and an alternative approach for a permanent, final remediation for the strontium plume will be considered. Insertion Point Milestone: FY03.

APPENDIX B

INTEGRATED NEEDS FOR GROUNDWATER/VADOSE ZONE INTEGRATION PROJECT - FY00

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APPENDIX B

INTEGRATED NEEDS FOR GROUNDWATER/VADOSE ZONE INTEGRATION PROJECT - FY00

The Groundwater/Vadose Zone (GW/VZ) Integration Project worked with the core projects in fiscal year 1999 (FY99) to prepare Integrated Needs for those needs associated with the characterization and assessment of the vadose zone, groundwater, and river system. In FY00, a similar process was used to develop four additional Integrated Needs for risk assessment and to make minor revisions to the needs developed in FY99. The Integrated Needs reflect the roadmap scope and collect the Science and Technology (S&T) needs prepared by the core projects and the Integration Project into 19 types of needs. The Integrated Needs are included in this appendix and are presented in the format specified by the U.S. Department of Energy (DOE) Office of Science and Technology. Each one calls out core project needs for both technology and science in its text. These core project needs can be found in the need data bases for the Office of Science and Technology.

B.1 ERC NEED STATEMENTS ASSOCIATED WITH HANFORD'S GROUNDWATER/VADOSE ZONE INTEGRATION PROJECT

The Hanford Site's Integration Project divides its work into eight technical elements. In addition to these technical elements, a System Assessment Capability is being developed by the Integration Project as the means to coordinate and collectively analyze the information from the other technical elements. The eight technical elements are:

- **Vadose Zone**
- **Groundwater**
- **River**
- **Inventory**
- **Risk**
- Monitoring
- Regulatory Path
- Remediation Options.

Of the eight technical elements that are part of the Integration Project, four of the elements highlighted in the bullets above (Vadose Zone, Groundwater, River, and Inventory) were addressed in detail in the GW/VZ Integration Project Specification (DOE/RL-98-48). In FY00, the project added a detailed description of the Risk technical element within the update of the Integration Project S&T Roadmap. The FY00 needs associated with the Integration Project were generated based on the technical content of these five technical elements. Some of the technology needs and science needs being carried forward to FY01 align with the Remediation Options technical element because the scope of this technical element includes the current remedial actions of the Environmental Restoration Contractor (ERC). Additional detail on the remaining technical elements will be added at a later date as the Integration Project progresses

through its planned activities.. Table 1 lists the FY01 needs (in bold type) and detailed needs as they relate to the technical elements of the Integration Project. The FY01 needs include the addition of needs associated with the Risk Technical Element. Additional needs related to the Remediation Technical Element will be added later in FY01. Needs associated with the Monitoring Technical Element will be added in the future.

The Integration Project needs are grouped by the technical element to which they align as shown in Table B-1.

Table B-1. Integration Project Technical Elements and Corresponding Hanford Needs.*

Vadose Zone	Groundwater	River	Inventory	Remediation Options
RL-SS27	**RL-SS32**	**RL-SS36**	**RL-SS40**	RL-SS01
RL-SS28	RL-SS03	**RL-SS37**	RL-WT01	RL-SS02
RL-SS23-S	RL-SS06	**RL-SS38**	RL-WT065	RL-SS03
RL-SS24-S	**RL-SS33**	**RL-SS39**	RL-WT04	RL-SS04
RL-SS26-S	RL-SS25		RL-WT041-S	RL-SS05
RL-SS27-S	**RL-SS34**		RL-WT052-S	RL-SS06
RL-SS30-S	RL-SS23-S		RL-WT056-S	RL-SS07
RL-WT035-S	RL-SS24-S		**RL-SS42**	RL-SS08
RL-WT053-S	RL-SS25-S		RL-WT02	RL-SS09
RL-WT029	RL-SS26-S			RL-SS10
RL-SS29	RL-SS27-S			RL-SS11
RL-SS28-S	RL-SS28-S			RL-SS12
RL-SS29-S	RL-SS31-S			RL-SS13
RL-SS31-S	RL-SS32-S			RL-SS14
RL-SS35-S	RL-SS35-S			RL-SS15
RL-WT053-S	**RL-SS35**			RL-SS16
RL-WT045-S				RL-SS17
RL-WT043-S				RL-SS18
RL-WT044-S				RL-SS19
RL-SS30				RL-SS20
RL-WT043-S				RL-SS23
RL-WT044-S				RL-SS24
RL-WT029				RL-SS25
RL-WT035-S				RL-SS26
RL-WT045-S				RL-WT017
RL-SS31				RL-WT018
RL-SS25-S				RL-WT061
RL-SS37-S				RL-SS33-S
RL-SS25				RL-SS34-S
RL-SS26				RL-SS36-S
RL-WT013				RL-WT046-S
RL-WT026				

*New needs for the Integration Project are shown in bold type. Right-justified needs are linked to the bolded need above it.

B.2 VADOSE ZONE TECHNICAL ELEMENTS

Table B-2. Vadose Zone Element Index to Linked Needs.

RL-SS27	Use of Field Data from Representative Sites to Elucidate Controlling Features and Processes for Contaminant Distribution
RL-SS28	Understand, Quantify and Develop Descriptions of Reactions and Interactions between Contaminants of Concern and Vadose Zone Sediments
RL-SS23-S	Chemical Speciation and Complexation in Site-Specific Groundwaters
RL-SS24-S	Chemical Binding on Site-Specific Mineral Surfaces
RL-SS26-S	Reaction Rates for Key Contaminant Species and complexes in Site-Specific Groundwaters
RL-SS27-S	Rates of Coupled Abiotic and biogeochemical Reactions Involving Contaminants in Hanford Subsurface
RL-SS30-S	Remedial Technology for Cs Beneath Waste Tanks
RL-WT035-S	Moisture Flow and contaminant Transport in Arid Conditions
RL-WT053-S	Contaminant Mobility Beneath Tank Farms
RL-WT029	Data and Tools for Performance Assessments
RL-SS29	Develop Descriptions of Contaminant Flow and Transport in the Vadose Zone
RL-SS28-S	Rates of Colloid Formation and Colloidal Transport of Contaminants in Site-Specific Goundwaters
RL-SS29-S	Effect of Subsurface Heterogeneities on Chemical Reaction and Transport
RL-SS31-S	Mathematical Formulations of Chemical Reaction/Material Transport
RL-SS35-S	Use of Chemical surrogates for Contaminants
RL-WT053-S	Contaminant Mobility Beneath Tank Farms
RL-WT045-S	Vadose Zone Flow Simulation Tool Under Arid Conditions
RL-WT043-S	Affect of Human and Natural Influences on Long-Term Water Distribution
RL-WT044-S	Distribution of Recharge Rates
RL-SS30	Understand and Quantify Water Movement in the Vadose Zone Using Uncontaminated Field Sites
RL-WT043-S	Affect of Human and Natural Influences on Long-Term Water Distribution
RL-WT044-S	Distribution of Recharge Rates
RL-WT029	Data and Tools for Performance Assessments
RL-WT035-S	Moisture Flow and contaminant Transport in Arid Conditions
RL-WT045-S	Vadose Zone Flow Simulation Tool Under Arid Conditions
RL-SS31	Provide Advanced Characterization Tools and Methods to Delineate Contaminant Plumes in the Vadose Zone and Relate Plume Distribution of Geochemical and Hydrogeological Properties
RL-SS25-S	Chemical Form and Mobility of Dense, Non-Aqueous Phase Liquids in Hanford Subsurface Transport of Contaminants
RL-SS37-S	Chemical Sensor Principles
RL-SS25	Improved, Cost-Effective Methods for Sub-Surface Access to Support Characterization and Remediation
RL-SS26	Improved Methods for Determining Distribution of Beta Emitting Contaminants in Subsurface Soils
RL-WT026	Tank Leak Detection Systems for Underground Single-Shell Waste Storage Tanks (SSTs)
RL-WT013	Establish Retrieval Performance Evaluation Criteria

B.2.1 Use of Field Data from Representative Sites to Elucidate Controlling Features and Processes for Contaminant Distribution (RL-SS27)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: Low-Level Waste (LLW) Soils 200 Area, ER-04: LLW Soils 100/300 Area, ER-03: MLLW Soils

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Use of field data from representative sites to elucidate controlling features and processes for contaminant distribution.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site Science and Technology Coordination Group (STCG) Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Currently, information on contaminant distribution, physical association, and chemical form in the vadose zone beneath waste sites of different source terms, ages, and water flow histories (e.g., cribs, tanks, trenches, spills) is not adequate to forecast whether future breakthrough to groundwater will occur (see for example, Hodges 1998, Johnson and Chou 1998, Narbutovskih 1998). For example, cores have been collected from a few locations impacted by leaked single-shell waste tanks (Freeman-Pollard et al. 1994, Myers et al. 1998), and debate exists as to whether the retrieved samples were or were not compromised. Moreover, little is known about the physical and chemical processes that are most significant over protracted contact times of the waste with the sediments in the vadose zone (Jones et al. 1998). These processes may differ significantly from short-term ones studied in the laboratory. Within this context, the effects of extreme waste chemistry, unsaturated water conditions, and complex, geologically controlled water flow paths add to the uncertainty of contaminant movement (Conaway et al. 1997, 1998). Without such information, little can be said about the long-term stability of the in-ground contaminant inventory; has it been immobilized or is it available for transport?

Hence, there is a need to investigate select field sites that are representative of major Hanford Site waste and disposal scenarios to develop rigorous conceptual models of governing processes for use in remediation and closure characterization assessment and performance validation. The development of conceptual models requires field sampling and study to understand 1) how contamination is distributed in the vadose zone beneath different types of waste sites with different source chemistries and different release histories, 2) the physical and chemical processes responsible for such distribution, and 3) whether contaminants have been immobilized or are still labile and migrating. The relationship between the contaminant distribution, moisture content, and the physical, chemical, microbiological, and geological characteristics of the subsurface sediments is needed as part of such an assessment. Critical information needs include the mineralogic association of contaminants, their mode of chemical binding, and interparticle location; presence of co-contaminants; and the physical/pore structure of the sediments that may imply the geochemical and hydrologic means of emplacement.

The elucidation of processes, lability, and current migration requires carefully formulated scientific characterization of field core samples that is closely linked with laboratory experimentation (e.g., contaminant desorption rates) to define key physical, chemical, and biologic aspects of the contaminant associations. Multiple core sampling at different times may be needed at a given site to assess migration. Rationalizing the existing contaminant distribution and forecasting future migration requires that water flow processes within the vadose zone at representative sites be characterized and understood (at least qualitatively), particularly those induced by preferential flow paths, high-density waste solutions, and/or other channeling effects. The primary technical gaps associated with the development of rigorous conceptual models of different waste sites and scenarios at the Hanford Site are as follows:

- The long-term geochemical reactions responsible for in-ground contaminant retardation and mobilization are insufficiently understood to predict when and where they have/will occur and their magnitude and direction. Defining these for different contaminants, waste types, release histories, and water volumes will provide chemical information to drive improved performance assessment models that include chemical reaction and insights to assess the migration potential of in-ground contaminants.

- Water flow pathways as driven by in situ geologic features in the vadose zone and waste properties such as temperature, electrolyte identity and composition, and density are insufficiently defined to estimate where waste solutions will migrate, the depth of their penetration, and sediment properties in which they will reside. An improved understanding of these in situ pathways beneath existing sites and their controlling features will provide necessary models and insights that can be extrapolated to other sites at the Hanford Site for prediction of where waste fluids are likely to migrate, their extent of dilution, and the possibility and timing of their breakthrough to groundwater.

- Hydrochemical effects of waste-sediment interaction such as porosity enhancement from mineral dissolution, pore plugging from precipitation of waste constituents such as aluminum, clay dispersion, or colloid generation have been insufficiently investigated to estimate when and where they will occur and their net effect on water and contaminant migration. Information on these linked chemical-hydrologic effects will provide key insights on the rates and direction of waste migration beneath single-shell tanks and the possibility that they may reach groundwater.

Functional Performance Requirements: The techniques applied or information that is obtained must delineate associations between physical, chemical, microbiological, and geological characteristics such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with enhanced conceptual models for processes in the vadose zone is needed in the FY99 to FY05 time frame to meet these objectives.

Problem Description: This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford Site soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system assessment and performance assessment (PA) models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that 1) underlie liquid waste disposal sites; 2) have the potential for leaks or leaching; and 3) have experienced past leaks and spills. Also included are selected

areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future. The primary suite of contaminants to be investigated include Cs-137, Sr-90, Co-60, U-235/238, Tc-99, Pu-239/240, Np-237, Am-241, I-129, carbon tetrachloride, and CrO_4^{2-}, but others, including co-contaminants (Na^+, NO_3^-) and indigenous ions (Ca^{2+}, Mg^{2+}), may be included as necessary depending on the nature of the specific sites studied.

Specific topics for this need include, in order of expected implementation, 1) collaboration with the River Protection Program (RPP) in the decommissioning of borehole 41-09-39 and the planned sampling of the vadose zone beneath SX-108 (FY00); 2) a new borehole at SX-115 in FY99; 3) a slant borehole beneath SX-108 in FY00, 4) quantification of the variations in recharge rates at existing waste sites (200-BP-1, etc.) of interest and assessment of these variations on contaminant migration rates; 5) studies of dense non-aqueous phase liquids (DNAPLs) (carbon tetrachloride) distribution and migration in the 200 West Area; and 6) selective high-impact collaborations with other site characterization efforts at cribs, ponds, and dry waste sites to be investigated as part of the 200, 300, and 100 Area environmental restoration efforts.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: Currently, information on physical association and chemical form of important contaminants in the vadose zone beneath waste sites of different source terms, ages, and water flow histories (e.g., cribs, tanks, trenches, spills) is not adequate to explain distribution of contaminants in the vadose zone today or to forecast future likely distribution. Little is known about the physical and chemical processes that are most significant over protracted contact times of the waste with the sediments in the vadose zone. Within this context, the effects of extreme waste chemistry, unsaturated water conditions and complex, geologically controlled water flow paths add to the uncertainty of contaminant movement.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the *Columbia River Comprehensive Impact Assessment* (CRCIA) Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on improved measurements of transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this activity. The activity that this need supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., Department of Defense [DOD], the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

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DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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B.2.2 Understand, Quantify, and Develop Descriptions of Reactions and Interactions Between Contaminants of Concern and Vadose Zone Sediments (RL-SS28)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-04: LLW Soils 100/300 Area, ER-03: MLLW Soils

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)

____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand, quantify and develop descriptions of reactions and interactions between contaminants of concern and vadose zone sediments.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Field data provide insight on the processes controlling the flux of key risk drivers and inventory elements to the groundwater. Quantification of these processes, and the bio- and hydrochemical reactions that contribute to them (e.g., adsorption, mineral precipitation and dissolution, biomineralization, matrix diffusion, pore plugging, and colloid formation) is ultimately required to defensibly forecast migration velocity, concentration, and breakthrough as needed for remediation assessment. Complications such as the impact of extreme waste conditions (e.g., high acidity, basicity, ionic strength); preferential water flow with implications to reactive surface area and waste/sediment ratios; geochemical reaction in thin water films present under unsaturated conditions; the effects of solvents, complexants, and mobile colloids on radionuclide mobility (e.g., plutonium); and the resuscitation and biogeochemical impact of microorganisms under conditions of artificial recharge are all significant in the Hanford Site vadose zone and measurements and study are needed to define and quantify their impact. An understanding of whether contaminants become more or less mobile with protracted contact times as well as the direction of change (e.g., greater or lesser mobility); and physical, chemical, and biological causes of such changes and how they are appropriately modeled are needed.

It is important to note that many laboratory studies have been performed on the interactions of contaminants with Hanford Site sediments from different actual and simulated waste matrices (see for example Serne et al. 1993; Kaplan and Serne 1995; Kaplan et al. 1996). These studies have defined empirical relationships between sorption parameters (e.g., K_d) sediment properties, and competitive ions (e.g., Ca^{2+}, Na^{+}) for some contaminants (e.g., Cs-137, Sr-90), and have defined expected ranges in K_d for others (e.g., Pu, Tc, Cr, U, Np, I). Such studies have also provided insights on the qualitative nature of retardation mechanisms (e.g., precipitation, ion exchange), and the potential impacts of extreme waste chemistry (Kaplan et al. 1998). While these studies have been well performed with the objective of parameterizing performance

assessment calculations (e.g., Smoot et al.1989), they fall short in defining the specifics of the transport process as needed for defensible long-term predictions of migration and in-ground stability. Furthermore, that data and associated understanding are fundamentally empirical; have not well defined the primary reaction processes; and poorly account for such important factors as co-contaminant ions, sediment properties, and reaction rate.

The primary technical gaps associated with reactions and interactions between wastes and vadose zone sediments are that the chemical and biologic reactions and colloidal transport processes responsible for contaminant retardation, immobilization, and mobilization are insufficiently understood or lack data on key parameters to allow for defensible predictions of their in-ground rates, extent, magnitude, and effect. This information is important to resolve important Hanford Site-specific geochemical questions for key contaminants such as 1) the potential colloid-facilitated transport of plutonium and the facilitating effects of DNAPL and complexants, 2) the existence of geochemical reactions (heterogeneous reduction, interparticle diffusion) potentially responsible for technetium immobilization in the vadose zone, and 3) the extent of in-ground fixation of sorbed Cs-137 and Sr-90. Specific issues that need to be addressed to resolve these technical gaps include the following.

- New insights and descriptive kinetic and thermodynamic information for reactions and interactions in the vadose zone based on key biogeochemical and hydrochemical reactions that control unsaturated chemical transport through the vadose zone are needed. The information is needed to assist in explaining solute attenuation profiles and chemical/ mineralogical speciation at contaminated sites and in developing improved process-level models for important reaction types, including colloid transport, as well as the hydrogeochemical effects on hydraulic properties and fluid flow. Specific information needed includes the following. Determination of the speciation and complexation of contaminants of interest in an aqueous phase distributed in the vadose zone (pristine and contacted by tank waste liquids) is needed (Science Need RL-SS23-S). Information is needed to understand the reactions that will affect the binding of contaminants in solution on secondary mineral surfaces, and on primary phases (Science Need RL-SS24-S). The reaction rates and the key reaction steps that control the speed with which a contaminant changes chemical form (e.g., speciation, complexation) and/or interacts with the surfaces of secondary minerals need to be quantified (Science Need RL-SS26-S). The reaction rates affecting cesium adsorption on micaceous secondary minerals exposed to chemical conditions similar to those generated by leaking high-level waste need to be quantified (Science Need RL-SS30-S). An understanding of the effect of coupled abiotic and biogeochemical reactions for which independent rates of reaction are known on contaminant form (e.g., speciation/complexation) is needed (Science Need RL-SS27-S).

- Sufficient scientific information is needed to support defensible simplification of complex contaminant reactions for tractable modeling at both waste site and sitewide scales as required for the sitewide model.

- The impact of extreme waste chemical conditions (high acidity, basicity, ionic strength, DNAPL presence, etc.) on contaminant mobility, the phases with which contaminants associate, hydrologic/geochemical properties and their distribution, and water-flow pathways need to be determined.

- Information is needed to determine whether contaminants become more or less mobile with protracted contact times. The information should include the direction of change (e.g., greater or lesser mobility) and physical, chemical, and biologic causes of such changes, and how are they appropriately described (modeled).

- Information is needed to understand the relationship between geochemical reactions and hydrogeological properties that affect transport through the vadose zone.

- Information is needed to understand to what extent laboratory-derived reaction parameters are descriptive of geochemical phenomena occurring in preferred flow paths and, if there are differences, what in situ features cause the differences.

- Techniques are needed to characterize surface areas of reacting solids in the field and determine to what extent the mineral surfaces are hydrologically accessible.

- Other existing S&T needs that relate to this need include RL-WT029, RL-WT035-S, and RL-WT053-S.

Functional Performance Requirements: The techniques applied or information that is obtained must describe and quantify reactions and interactions between contaminants of concern and vadose zone sediments such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with reactions and interactions between contaminants and vadose zone sediments is needed in the FY99 to FY05 time frame to meet these objectives.

Problem Description: This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford Site soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system and performance assessment models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that 1) underlie liquid waste disposal sites, 2) have the potential for leaks or leaching, and 3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include 1) new insights and descriptive kinetic and thermodynamic information to assist in explaining solute attenuation profiles and improved process-level modeling, 2) constitutive relationships to be used in reactive transport models for history matching of contaminant distribution at representative field sites, and 3) knowledge to support defensible simplification of complex contaminant reactions for tractable modeling at both waste sites and sitewide scales during performance and remediation assessments. The key Hanford Site contaminants include risk drivers (Tc-99, I-129, carbon tetrachloride, CrO_4^{2-}), major inventory constituents (Cs-137, Sr-90, Co-60, U-235/238,), and other elements of concern (Pu-239/240, Np-237, Am-241).

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: The chemical and biologic reactions and colloidal transport processes responsible for contaminant retardation, immobilization, and mobilization are insufficiently understood or lack data on key parameters to allow for defensible predictions of their in-ground rates, extent, magnitude, and effect. This information is important to resolve important Hanford Site-specific geochemical questions for key contaminants such as 1) the potential colloid-facilitated transport of plutonium and the facilitating effects of DNAPLs and complexants, 2) the existence of geochemical reactions (heterogeneous reduction, interparticle diffusion) potentially responsible for technetium immobilization in the vadose zone, and 3) the extent of in-ground fixation of sorbed Cs-137, Sr-90, and carbon tetrachloride.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on improved measurements of transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this activity. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

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B.2.3 Develop Descriptions of Contaminant Flow and Transport in the Vadose Zone (RL-SS29)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-04: LLW Soils 100/300 Area, ER-03: MLLW Soils

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Develop descriptions of contaminant flow and transport in the vadose zone.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River

resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The approach to date has been to use relatively simple models to describe contaminant transport in the vadose zone. These models are "simple" in that they lump many of the complexities into relatively few input parameters. For example, the potentially complex aspects of fluid chemistry and mineralogy are treated with a sorption coefficient and a porosity. The complexities of flow are described with two dispersion coefficients. Soil hydrological properties are allowed to change only with depth. Recharge rates, and consequently flow, are assumed to be constant with time rather than episodic, and coarse gridding for numerical models tends to smooth the calculated flow and mask the potential creation of fast paths in the real world. The sum of all of these simplifications and approximations is that the resultant calculated contaminant mobility is subject to very large errors. Furthermore, predictions made with these models cannot hold up to critical technical scrutiny, and more importantly, they fail to match observations that have and will be made by monitoring and characterization activities.

Previously employed approaches for modeling vadose zone transport do not capture essential processes that affect contaminant migration at the Hanford Site. Previous modeling efforts have used decoupled approaches even though radionuclide and contaminant transport may involve fully coupled thermal-hydrological-mechanical-chemical processes. In addition, the effect of chemical coupling (through fluid density modification and mineral/precipitation dissolution) on fluid flow and radionuclide transport have been ignored. These types of simplifications may introduce unacceptable errors to long-term assessment of contaminant transport. Preferential flow in particular is considered to be an important contaminant transport mechanism in the Hanford Site vadose zone.

Improvement in modeling of vadose zone transport requires developing models that can capture the important complexities. This development will take the form of enhancing existing codes to represent additional processes, running them with finer grids and time spacings, and simulating some of the heterogeneities and episodicities. Partial coupling of physical and chemical processes may also be needed. It is expected that some potentially complicating processes can be demonstrated to be insignificant, and that the transport behavior produced in the complex models can be abstracted into more highly parameterized models for sitewide assessment and long-term predictions.

The specific technical gaps associated with modeling of contaminant transport in the vadose zone are as follows:

- Information is needed to assess the effects of high-ionic-strength aqueous solutions under varying redox and pH conditions present in some of the leaking storage tanks on the rate of metal/radionuclide migration. Although it is known that high-ionic-strength solutions change the partitioning behavior of strongly sorbed nuclides, especially alkalis such as Cs-137, it is not known quantitatively for a range of likely conditions, nor is it known how fast fluids are neutralized by reaction with the soil matrix, how much this fluid-rock interaction changes the sorption properties of the matrix, and whether the high densities of fluids cause them to flow downward fast enough that the effective surface area for sorption is greatly reduced. A further concern is with non-isothermal effects near the tanks, and in the seepage of highly radioactive tank fluids.

- Techniques are needed to estimate flow, transport, and reaction/interaction parameters from data collected at different scales of observation and for transferring geohydrological information from one site to another with an understanding of the limitations of these techniques. These are long-standing issues in hydrological modeling, but the approach used needs to be tailored to the type of system being modeled, and there needs to be enough data to estimate what sacrifices in terms of uncertainty are being made by using data measured at one scale to represent larger and smaller scales.

- Techniques are needed to adequately account for spatial and temporal heterogeneity that impacts contaminant transport. There is a need to model water seepage, and associated mass transport, on the actual scale on which these processes are taking place. This may require spatial resolution of order 0.1 - 1 m, and temporal resolution of order 1 hr - 1 day. How such resolution can be reconciled with sitewide modeling and assessment on time scales of 10 to100 years is a major challenge. The episodic nature of seepage, and associated hysteresis and mixing effects must also be accounted for. Episodic and intermittent features can come into play from the nature of precipitation and runoff, from tank leaks, and when considering sluicing to remove tank contents. The temporal structure of unsaturated zone seepage may be as important as the spatial structure (Science Needs RL-WT045-S).

- Improved multiphase-multicomponent reactive transport models that adequately describe contaminant migration in the Hanford Site vadose zone are needed. These models should include groups of specialized submodels relating to specific waste chemistry and other features that support site-specific and provide a basis for sitewide assessments. Current vadose zone modeling uses decoupled approaches. There are some process aspects (chemical reaction-induced changes in porosity, permeability, reactive surface area) that can only be captured through fully coupled modeling.

- Approaches for considering and incorporating uncertainty in transport modeling are needed to better communicate what is or is not known. This is also a widely appreciated aspect of hydrological modeling, but there are many possible approaches, and one or more need to be developed, decided upon, and gain the acceptance of the concerned community.

- Information is needed to understand which secondary minerals form as colloids in groundwater, the importance of biosorption, the nature of the chemical interactions between contaminants of interest and the surfaces of inorganic and organic colloids, and the effect of colloids on contaminant transport at the Hanford Site (Science Need RL-SS28-S).

- Information is needed to understand how the physical and chemical properties of the specific Hanford formations affect the transport of chemical solutes and colloids (Science Need RL-SS29-S).

- Techniques and information are needed to quantify the migration rate of contaminants through the vadose zone. Model formulations are needed for the chemistry and physics that describe the dispersal and longevity of subsurface contaminant plumes for site conditions, contaminant chemistry and reactivity, and hydraulic properties at the Hanford Site (Science Need RL-SS31-S). The evolution of the present distribution of contaminants, both radioactive and nonradioactive (particularly Cs-137 but also plutonium, Tc-99, Sr-90, chromium, carbon tetrachloride, and nitrate), beneath the tank farms and past-practice disposal sites and to evaluate their potential mobility under all "leave or retrieve" options needs to be understood and quantified (Science Need RL-WT053-S). Techniques are needed to use readily measured chemical analogues (similar group, charge, ionic size) to contaminants of interest to assess the behavior of difficult-to-measure contaminants in the Hanford Site subsurface (Science Need RL-SS35-S).

- Other science needs that relate to this need include RL-WT043-S and RL-WT044-S.

Functional Performance Requirements: The techniques applied or information that is obtained must describe and quantify contaminant transport in the Hanford Site vadose zone or provide relevant parameters or mathematical formulations such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with descriptions contaminant transport in the vadose zone is needed in the FY99 to FY03 time frame to meet these objectives.

Problem Description: This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford Site soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system and performance assessment models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that 1) underlie liquid waste disposal sites, 2) have the potential for leaks or leaching, and 3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include 1) scientifically defensible predictive tools and 2) detailed process-level reactive transport models to provide a foundation for site-scale models for sitewide assessments.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: Previously employed approaches for modeling vadose zone transport do not capture essential processes that affect contaminant migration at the Hanford Site. Previous modeling efforts have used decoupled approaches even though radionuclide and contaminant transport may involve fully coupled thermal-hydrological-mechanical-chemical processes. In addition, the effect of chemical coupling (through fluid density modification and mineral/precipitation dissolution) on fluid flow and radionuclide transport have been ignored. These types of simplifications may introduce unacceptable errors to long-term assessment of contaminant transport.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on improved measurements of transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this activity. The activity that this need supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.2.4 Understand and Quantify Water Movement in the Vadose Zone Using Uncontaminated Field Sites (RL-SS30)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-04: LLW Soils 100/300 Area, ER-03: MLLW Soils

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand and quantify water movement in the vadose zone using uncontaminated field sites.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The rate of movement of contaminants from buried waste through the vadose zone to groundwater is presently not well documented for Hanford Site conditions. Neither the chemical nor physical mechanisms for flow and transport in the vadose zone are well understood. At present, few boreholes in the tank farm area have been cored and analyzed for both hydraulic properties and chemistry (Freeman-Pollard et al. 1994, Myers et al. 1998) and rates of vadose zone migration are still indeterminate for most, if not all, of the contaminants of concern. Moreover, little is known about the physical and chemical processes that are most significant over protracted contact times of the waste with the sediments in the vadose zone (Jones et al. 1998), and this has led to predictions of flow and transport that are plagued with large uncertainties. These processes may differ significantly from short-term ones studied in the laboratory. Within this context, the effects of extreme waste chemistry, unsaturated water conditions, and complex, geologically controlled water flow paths add to the uncertainty of contaminant movement (Conway et al. 1997, 1998). Without such information, little can be said about the long-term stability of the in-ground contaminant inventory; has it been immobilized or is it available for transport? Recent groundwater monitoring reports (see for example, Johnson and Chou 1998, Hodges 1998, Narbutovskih 1998) have also highlighted some of the uncertainties in vadose zone/groundwater interactions.

Rates of transport to groundwater may range from decades to thousands of years, depending on the nature of the waste and the amount and location of the water sources that mobilize waste and carry it to the water table. No direct measurement of net water infiltration (the primary driver for fluid migration in the vadose zone) has been made at any Hanford waste site (Smoot et al. 1989, Ward et al. 1997). In addition, accelerated flow paths (channels, etc.) may funnel contaminants more rapidly than current hydrologic models predict (Conaway et al. 1997, 1998) via preferred pathways caused by geologic features, by dissolution of sediments from extreme wastes, or unstable wetting fronts. Fast flow pathways may be tortuous and of limited horizontal extent, so that locating them with widely spaced boreholes will be difficult. Temporal variations in vadose zone fluxes are also expected as a result of variations in surface-controlled net water infiltration, spatially distributed preferential flow paths, and temporally/spatially discrete waste water discharges. These temporal fluxes are important and are assumed to cause observed transient peaks in groundwater contamination levels. Elucidating these phenomena is important to the understanding of the nature and extent of contamination determined during field characterization at contaminated sites and, subsequently, forecasting future extent of contamination during and after remediation.

The primary technical gap associated with transport in the vadose zone is an insufficient understanding of uncertainties in source terms, geohydrologic properties, and chemical interactions that combine to make current modeling of contaminant transport in the Hanford Site vadose zone questionable. The sediments beneath waste sites at the Hanford Site are known to be highly heterogeneous (e.g., interbedded sand, silts, and gravels). These heterogeneities, coupled with temporal and spatial variations in net water infiltration (via past liquid discharges, water line leaks, meteoric sources, etc.) and variable chemical interactions, complicate description and understanding of contaminant transport, often making an evaluation of transport at contaminated sites ambiguous.

Specific issues that need to be addressed to resolve this technical gap include the following:

- Information on the nature and extent of preferred flow paths in the Hanford Site vadose zone sediments is needed. Specific information needed includes the following. A determination of which geologic and lithologic features area associated with preferred flow paths and under what moisture conditions they function as conduits is needed. Techniques to determine the length scales over which preferred flow paths are present at the Hanford Site are needed. Information is needed to determine which waste chemistries are conducive to formation of preferred flow paths and what hydrochemical reactions are most important in the field and to what extent they control in situ flow velocities and direction. Information to determine to what extent laboratory-derived reaction parameters are descriptive of geochemical phenomena occurring in preferred flow paths and, if differences are observed, what in situ features cause the differences. In addition, information is needed to determine whether fast radionuclide migration pathways through the vadose zone exist and, if so, their origin. Appropriate model formulations that include the impact of preferential flow pathways and the near-field impacts of thermal and pressure (advective) enhancements in predictive flow and transport models are also needed.

- Techniques are needed to determine the frequency of preferred flow paths in the Hanford Site vadose zone, as well as an understanding of the geologic and lithologic features and moisture content associated with the flow paths. Documentation of the distribution of the flow pathways will provide a basis for more realistic predictions of early arrival of contaminant plumes. Quantification of the flow pathways may help explain why mobile elements such as Tc-99 and nitrate are being discovered in elevated concentrations in some groundwater wells near tank farms and not in others (Science Need RL-WT035-S).

- Information is needed to determine the extent to which hydrochemical reactions that create preferred pathways influence the in situ flow velocity and direction. These reactions influence the in situ flow velocity and direction. Parameters are needed that clearly define the interactive role of waste chemistry and hydrologic reactivity when physically hot brine interacts with Hanford Site sediment and alters the hydrologic flow regime (Science Need RL-WT035-S).

- Information is needed to determine the best field-scale values and statistics for hydraulic and geochemical parameters and the approach to best derive and transfer these parameters. There is a need to develop approaches that best derive and transfer these parameters to other locations and depths in the Hanford Site vadose zone (Science Need RL-WT035-S).

- Information is needed to determine net water infiltration for a given waste site at the Hanford Site. The variability may include vegetation dynamics (resulting from disturbances, fires, drought) and its impact on the local and regional recharge rates that ultimately control contaminant migration rates. The spatial and temporal variation of the water infiltration rates can drastically affect the amount of contaminant moving to groundwater from a given waste site. Such information has been lacking in the predictive modeling of risk and dose from Hanford Site waste areas, and the impact of these variations needs to be documented (Science Needs RL-WT035-S, RL-WT044-S and Technology Need RL-WT029).

- Means to quantify the distribution of recharge throughout the Hanford Site as well as through an individual waste site, the variability (uncertainty) possible in the distribution of recharge, and the time delay between recharge through the land surface and that into the water table are needed (Science Need RL-WT044-S).

- The interaction of the factors that affect water recharge variables across a sparsely vegetated landscape over long times (thousands of years) needs to be understood and incorporated into estimates of long-term rates of water infiltration (Science Need RL-WT044-S).

- The impact of future land and water use and potential climate changes on water infiltration needs to be understood and incorporated into modeling efforts to predict the transport of contaminants (Science Need RL-WT043-S).

- Another science need that relates to this need is RL-WT045-S.

Functional Performance Requirements: The techniques applied or information that is obtained must delineate water infiltration rates or relate water movement to Hanford Site waste site geology and surface features such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with water movement in the vadose zone is needed in the FY99 to FY03 time frame to meet these objectives.

Problem Description: This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford Site soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system and performance assessment models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that 1) underlie liquid waste disposal sites, 2) have the potential for leaks or leaching, and 3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include 1) a comprehensive data set with clear boundary conditions and known source functions to validate conceptual and numerical models of water movement through the Hanford Site vadose zone; 2) procedures for scaling up laboratory-derived parameters (e.g., chemical reaction parameters, hydraulic properties and 3) input to site-specific and sitewide assessments that provide realistic assessment of plume migration rates in the vadose zone sediments at the Hanford Site.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of uncertainties in source terms, geohydrologic properties, and chemical interactions that combine to make current modeling of contaminant transport in the Hanford Site vadose zone questionable. The sediments beneath waste sites at Hanford are known to be highly heterogeneous (e.g., interbedded sand, silts, and gravels). These heterogeneities, coupled with temporal and spatial variations in net

water infiltration (via past liquid discharges, water line leaks, meteoric sources, etc.) and variable chemical interactions, complicate description and understanding of contaminant transport, often making an evaluation of transport at contaminated sites ambiguous.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on a clear understanding transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this activity. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

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B.2.5 Provide Advanced Characterization Tools and Methods to Delineate Contaminant Plumes in the Vadose Zone and Relate Plume Distribution to the Distribution of Geochemical and Hydrogeological Properties (RL-SS31)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-04: LLW Soils 100/300 Area, ER-03: MLLW Soils

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Provide advanced characterization tools and methods to delineate contaminant plumes in the vadose zone and relate plume distribution to the distribution of geochemical and hydrogeological properties.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps

described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

To support both site-specific and sitewide assessments that lead to effective remediation, advanced characterization tools and methods are needed to determine the nature and extent of contamination and to support field investigations to elucidate key features and processes that control contaminant migration. At present, we do not know where more than a few percent of the contaminants are located in the vadose zone (GAO 1989, Ward et al. 1997). Spectral gamma logging of tank farm subsurface contamination has not provided information about the risk drivers (Tc-99, I-129, etc.) that currently reside in the vadose zone and are leaking into the groundwater (GJPO 1996, 1998; Conaway et al. 1997, 1998). Advanced characterization tools will provide that information, which is key to knowing when groundwater might be impacted by contaminants that are moving to the water table at accelerated rates (Johnson and Chou 1998, Hodges 1998, and Narbutovskih 1998) from Hanford Site waste sites (tanks, cribs, trenches, etc.). This information is presently lacking in all the waste management areas (100, 200, 300) but is particularly critical to waste disposal decision in the 100 and 200 Areas, where some wastes may be left in place and isolated with engineered barriers. The potential for migration and the monitoring verification of the contaminant mobility will depend on characterization tools that currently are not deployed at the Hanford Site.

The primary technical gap associated with delineating contaminant plumes in the vadose zone is insufficient soil, geophysical, geochemical, and hydrological data or methods to resolve subsurface heterogeneities, characterize geohydrologic properties, and map contaminant distributions at different scales in the vadose zone. This information is important to determine the physical and chemical properties/parameters of the vadose zone, as well as the water and contaminant distribution and flux for use in assessing the potential for future migration or remobilization of contaminants. Specific issues that need to be addressed to resolve this technical gap include the following:

- Characterization methods are needed to define the in situ physical and chemical aspects of the vadose zone, and average field-scale properties describing fluid flow and reaction. These methods need to have the sensitivity to characterize subsurface geohydrologic and geochemical properties with sufficient accuracy to permit prediction of contaminant fate and transport. Specific information needed includes the following: Techniques are needed to determine the distribution of subsurface heterogeneities (natural and those created by waste interaction with the porous medium) that may influence the distribution of soil water and contaminants. Additionally, techniques are needed to delineate the three-dimensional (3D) distribution of geohydrological properties in the vadose zone. Techniques are also needed to extrapolate the classical measurements of geohydrologic and transport properties made on small, homogeneous soil cores and in small near-surface experiments to the pertinent field scale at which soil parameters exhibit complex natural heterogeneity.

- Characterization methods are needed to delineate the 3D size and shape of contaminant plumes in the vadose zone. Specific information needed includes the following: Information is needed about how contamination is distributed in the vadose zone beneath different types of waste sites with different source chemistries and different release histories. Information is needed to understand the existing physical, chemical, and mineralogical associations of contaminants and co-contaminants and determine the primary processes that have formed these associations. Information is needed to understand the relationships between contaminant distribution, moisture content, and the physical, chemical, microbiologic, and geologic characteristics of the subsurface sediments. In addition, techniques are needed to map groundwater contaminants and other dissolved species that have reached the groundwater back to their sources.

- Information is needed to determine the chemical form and mobility of dense, non-aqueous phase liquids (DNAPLs) and related contaminants, such as chlorinated solvents in contact with 1) pore water and 2) secondary minerals. The distribution of DNAPLs in the vadose zone can greatly affect the cleanup efficiencies and thus affect costs of cleanup (e.g., over 80% of the carbon tetrachloride inventory is assumed to lie above the water table, but its distribution within the vadose zone is unknown). Determination of form and distribution of DNAPLs in the vadose zone will help prioritize cleanup strategies and may greatly reduce cleanup time and costs (Science Need RL-SS25-S).

- Information is needed to understand the physics and chemistry principles that underlie more accurate, more sensitive, and higher resolution measurements of contaminant concentrations in the aqueous and solid (surface) phases. Recent theoretical developments on electromagnetic and electrical field analysis in zones containing high metal contents (buried pipes, well casings, etc.) could lead to less expensive methods for minimally intrusive measures of subsurface contaminant plumes (Science Need RL-SS37-S).

- The Hanford Site contains large volumes of contaminated vadose zone and aquifer soils. In some areas, these soils are located at depths of 152 m (500 ft), while access to other soils is restricted by the presence of surface or near-surface objects such as buildings or underground tanks. The Hanford Site geology also is quite varied and ranges from unconsolidated silty sands to gravels and cobbles. Cost-effective technologies that allow access to this wide variety of sediments for both characterization and remediation are required (Technology Need RL-SS25).

- Contaminants with low distribution coefficients and long half-lives, such as Tc-99 and I-129, tend to represent the greatest health risks in long-term risk assessments for the 200 Area tank farms. Also, strontium contamination in the 100 Area soils and groundwater presents a near-term environmental concern due to its close proximity to the Columbia River. However, it is difficult to measure the inventories and distribution of these contaminants because they only emit beta particles that do not penetrate the surrounding soil. Therefore, the only way to currently obtain data in the vadose zone is through the costly collection of soil samples. Improved, more cost-effective methods of accessing contaminated soils, taking soil samples,

and/or measuring the concentration of beta-emitting contaminants are required (Technology Need RL-SS26).

- Other technology needs that relate to this need include RL-WT013 and RL-WT026.

Functional Performance Requirements: The techniques applied or information that is obtained must delineate contaminant plume distributions and geochemical and hydrogeological property distributions such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with delineating contaminant plumes in the vadose zone is needed in the FY99 to FY02 time frame to meet these objectives.

Problem Description: This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford Site soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system and performance assessment models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that 1) underlie liquid waste disposal sites, 2) have the potential for leaks or leaching, and 3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include 1) improved downhole and minimally intrusive methods for determination of physical and chemical properties/parameters of the Hanford Site vadose zone and 2) improved downhole and minimally intrusive methods for determination of contaminant distribution and flux.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There are insufficient soil, geophysical, geochemical, and hydrological data or methods to resolve subsurface heterogeneities, characterize geohydrologic properties, and map contaminant distributions at different scales in the vadose zone. This information is important to determine the physical and chemical properties/parameters of the vadose zone as well as the water and contaminant distribution and flux for use in assessing the potential for future migration or remobilization of contaminants.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None

Consequences of Not Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on improved measurements of transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this advanced characterization activity. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

Conaway, J. G., R. J. Luxmoore, J. M. Matuszek, R. O. Patt, and D. S. Shafter, 1997, *TWRS Vadose Zone Contamination Issue Expert Panel Status Report*, DOE/RL-97-49, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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Hodges, F. N., 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site*, PNNL-11809, Pacific Northwest National Laboratory, Richland, Washington.

Johnson, V. G. and C. J. Chou, 1998, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*, PNNL-11810, Pacific Northwest National Laboratory, Richland, Washington.

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B.3 GROUNDWATER TECHNICAL ELEMENTS

Table B-3. Groundwater Element Index to Linked Needs.

RL-SS32	Understand and Quantify the Relationship Between Contaminant Sources, Vadose Zone Plume Properties and Groundwater Plume Properties with a Focus on the Groundwater-Vadose Zone Interface
RL-SS03	Improved, Real-Time, In-Situ Detection of Carbon Tetrachloride in Groundwater
RL-SS06	Improved, Real-Time, In-Situ Detection of Hexavalent Chromium in Groundwater
RL-SS33	Provide Means to Delineate Regional Groundwater Plumes in Three Dimensions and Define a Science Basis for Addressing Scaling Issues in Hanford Groundwater
RL-SS25	Improved, Cost-Effective Methods for Sub-Surface Access to Support Characterization and Remediation
RL-SS34	Understand, Quantify and Develop Descriptions of Biogeochemical Reactions and Interactions Between Contaminants of Concern and Aquifer Sediments to Describe Biochemical Reactive Transport
RL-SS23-S	Chemical Speciation and Complexation in Site-Specific Groundwaters
RL-SS24-S	Chemical Binding on Site-Specific Mineral Surfaces
RL-SS25-S	Chemical Form and Mobility of Dense, Non-Aqueous Phase Liquids in Hanford Subsurface Transport of Contaminants
RL-SS26-S	Reaction Rates for Key Contaminant Species and Complexes in Site-Specific Groundwaters
RL-SS27-S	Rate of Coupled Abiotic and Biogeochemical Reactions Involving Contaminants in Hanford Subsurface
RL-SS28-S	Rates of Colloid Formation and Colloidal Transport of Contaminants in Site-Specific Groundwaters
RL-SS31-S	Mathematical Formulations of Chemical Reaction/Material Transport
RL-SS32-S	Reactivity of Organics in the Hanford Subsurface
RL-SS35-S	Use of Chemical surrogates for Contaminants
RL-SS35	Provide Means to Quantify the Flux of Contaminant Between the Groundwater and the Columbia River

B.3.1 Understand and Quantify the Relationship Between Contaminant Sources, Vadose Zone Plume Properties and Groundwater Plume Properties at Hydrologic Boundaries with a Focus on the Groundwater-Vadose Zone Interface (RL-SS32)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand and quantify the relationship between contaminant sources, vadose zone plume properties and groundwater plume properties at hydrologic boundaries with a focus on the groundwater-vadose zone interface.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This specific need addresses the near-source vertical distribution of contaminants in groundwater. The primary technical gap is an inadequate understanding of the processes that control the transport of contaminants across the vadose zone/groundwater interface and the resulting vertical distribution within the aquifer. Variables involved include contaminant properties; waste characteristics such as density, chemistry, and volume of the waste; influences of artificial water recharge; and the nature of the contaminant release from the vadose zone to the groundwater. This information is important to resolve current inventory estimates associated with groundwater plumes and to estimate the flux of contaminants from the vadose zone to groundwater. Information about vertical distribution of the groundwater plume near the source is also important to help infer how contaminants move through the vadose zone. For example, deeply distributed carbon tetrachloride in the aquifer beneath Plutonium Finishing Plant disposal sites implies drainage of a DNAPL through the vadose zone that "settles" in the aquifer. Contaminant concentrations that are highest in the capillary fringe, or at the very top of the aquifer, would imply unsaturated flow through the vadose zone and a low pore fluid density. Specific needs to address the vadose zone/groundwater interface technical gap include the following:

- Innovative approaches to determine the rate and nature of contaminant delivery from the vadose zone to the groundwater in 3D are needed. These approaches include the reevaluation of historical data to infer vertical distribution of contaminants in groundwater as well as demonstrating effective depth-discrete sampling tools (related to Technology Needs RL-SS03 and RL-SS06).

- Evaluation of temporal issues and relating these issues to seasonal or source term issues is needed to support sitewide assessment. Infiltration rates from the vadose zone to the groundwater control the quantity and timing of contaminant flux.

- Developing an understanding of the relationship between vadose zone capillary fringe and 3D plume geometry in the groundwater near the contaminant sources and controlling processes for contaminant migration through the vadose zone is needed to provide diagnostic information. Recent comments by a peer-review panel for the proposed Hanford Sitewide groundwater model pointed out the need for addressing sources of uncertainty, including those introduced by alternate conceptual models. The interface between the vadose and groundwater is a key relationship that needs to be better understood to support analyses that will be performed.

- Techniques that provide representative physical and chemical data during borehole/well installation to delineate contaminant plume distribution and chemistry in the capillary fringe and in the aquifer near the water table are needed. Techniques are also needed to assess the representativeness and quality of sample/data collection methods for the capillary fringe and groundwater.

Functional Performance Requirements: The techniques applied or information that is obtained must delineate contamination and describe processes at the groundwater-vadose zone interface such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project. The information must provide a better understanding of current conditions, and the ability to assess potential future conditions for near- and long-term scenarios.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with the groundwater-vadose zone interface is needed in the FY00 to FY04 time frame to meet these objectives.

Problem Description: This need falls under the Groundwater Technical Element within the S&T Endeavor. The Groundwater Technical Element is intended to address and resolve scientific issues related to understanding the role of groundwater in the overall migration of contaminants from the Hanford Site. The objective of the Groundwater Technical Element is to enhance protection of the Columbia River and its environs by 1) determining the existing distributions of contaminants with particular emphasis on 3D distribution, especially at the interfaces with the vadose zone and the river, and 2) enhancing the understanding of geological, chemical, geochemical, and hydrologic controls for future movement of contaminants. Detection

of contaminants in groundwater monitoring wells underlying tanks, cribs, landfills, and other sources has often been the first indication of releases and migration. Understanding the flux and dynamics of vadose-capillary fringe-groundwater contaminant transfer and plume migration in three dimensions is critical to reconstructing vadose zone transport. On a larger scale, transport processes in groundwater control migration to extraction wells or surface water bodies (e.g., the Columbia River), define future risk scenarios, and affect the potential for optimized cleanup. An implicit goal of this research is to provide sufficient knowledge and data and identify existing and new S&T for input to DOE's decision-making process for Hanford Site cleanup.

This technical element provides the information, analytic capabilities, and understanding required for improving the technical basis for assessments of Hanford Site impacts to groundwater resources and the Columbia River. Groundwater represents an important portion of the potential exposure path and is the link between the source/vadose system and receptors at a well or the river. The technical scope of the groundwater element complements that of the vadose zone element by extending the characterization work into the saturated sediments under the Hanford Site. The saturated zone includes the capillary fringe, the unconfined aquifer, aquitards, and uppermost confined aquifers. The technical scope of the groundwater element also complements that of the river element by providing input to contaminant flux to the river and other interactions between the groundwater and Columbia River. Major topics include 1) the distribution of contamination within the saturated sediments; 2) the hydrology, geology, geochemistry, and microbiology of the saturated zone; 3) groundwater flow and transport of contamination; and 4) numerical models that depict the movement of water and contaminants.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of the relationship between vadose zone contamination properties (e.g., the plume distribution, contaminant source properties, waste properties such as density, chemistry, and volume of the waste, and influences of artificial water recharge) and the nature of the contaminant release from the vadose zone to the groundwater. This information is important to resolve current inventory estimates associated with groundwater plumes and to estimate the flux of contaminants from the vadose zone to the groundwater. Information about the groundwater plume below the discharge area is also important to help infer transport of contaminants through the vadose zone.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None

Consequences of Not Filling Need: If this need is not filled, baseline approaches will be used that may not provide an appropriate delineation of contaminant distribution and relation of plumes to sources. Thus, there will be more uncertainty in the technical basis used for decisions. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. The activity that this need supports will also be used to support development of the System Assessment Capability (SAC) as part of the GW/VZ Integration Project. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.3.2 Techniques to Delineate Groundwater Plumes in Three Dimensions and Define a Scientific Basis for Addressing Scaling Issues in Hanford Groundwater (RL-SS33)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
___ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
___ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Techniques to delineate groundwater plumes in three dimensions and define a scientific basis for addressing scaling issues in Hanford groundwater.

Need/Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This need focuses on the extension of our current knowledge of groundwater characteristics to support sidewide assessments. The structure and development of the regional groundwater plumes is critical to estimating inventory of contaminants in groundwater for sitewide assessments. This plume structure also provides information about controlling hydrogeology and is critical to calibrating and documenting the quality/performance of numerical models. In addition, hydrogeological characterization at multiple scales is needed to understand and predict the flows and transport at the Hanford Site. As recommended by the peer review panel for the Hanford Sitewide groundwater model in a recent review, the first step in developing this knowledge is evaluating the sources of uncertainty in the model. This will provide direction to areas where the characterization can have the greatest impact in reducing uncertainty.

The proposed need emphasizes the need for understanding the vertical penetration of contaminant plumes, both near sources and in regional plumes as contaminants travel toward the Columbia River. Developing a technically based understanding of this 3D behavior is important at several scales and is needed to reduce the uncertainty and improve the SAC at the Hanford Site. Until recently, most site modeling and characterization of the groundwater has been performed in two dimensions with emphasis on the upper portion of the water table. Contaminants penetrating below this interval as a result of regional infiltration, geological features, or waste characteristics have not been fully addressed.

Near a waste disposal source, the vertical concentration profile and contaminant penetration are diagnostic of the release (volume, contaminant concentrations, and waste properties). Regionally, infiltration and boundary conditions result in plume trajectories that dip downward near the source, and then upward near the Columbia River. In both of these cases, the penetration and 3D plume geometry is strongly dependent on geological controls. Understanding this behavior will improve interpretation of data and will improve the robustness of models. This is especially important as predictions are extended to future conditions that differ significantly from the present day – i.e., what happens to the plumes when future groundwater levels decline and the water table is in the Ringold Formation instead of the Hanford formation?

This need targets technologies and approaches to fill this data gap in creative and cost effective ways and in a manner that is compatible with Hanford Site requirements and stakeholder values.

Specific issues that need to be addressed to resolve this technical gap include the following:

- Information is needed to understand how to incorporate the 3D properties of contaminant plumes and regional-scale data into predictions of plume fate and transport. To provide input to fate transport models, techniques are needed to obtain representative data for the 3D distribution and chemistry of groundwater contaminant plumes and depth-discrete and regional-scale information on aquifer hydrogeological properties. Means to assess the representativeness and quality of these sample/data collection methods are also needed.

- As part of the analysis of fate and transport for contaminants, information is needed to understand the relationship between the migration pattern of high-mobility contaminants (e.g., H-3, Tc-99, and nitrate) and the migration pattern of moderate to low-mobility (e.g., I-129, Sr-90, Cs-137, and Co-60) contaminants.

- An improved understanding of groundwater conditions such as high water levels to the east of the Columbia River is needed to describe and predict the subsurface distribution of contaminants. High water levels in east of the river will deflect contaminant plumes and alter the outcrop location – moving it upstream and toward the Hanford Site bank. Understanding this large scale, 3D concept will improve the technical basis for river impact assessment.

- Information is needed to determine which scales of physical/hydrological heterogeneity definition are needed to effectively predict contaminant fate and transport for both site-specific and sitewide assessments. Additionally, information is needed to understand how to relate hydraulic measurements acquired with different support scales or different volumes of investigation.

- An approach for defining and accounting for uncertainty of 3D contaminant distribution is needed for conceptual and numerical modeling of regional and site-specific plume structure.

- Information is needed on behavior of DNAPL and light non-aqueous phase liquid wastes at the Hanford Site. These wastes, such as dense carbon tetrachloride and co-contaminants dissolved in the carbon tetrachloride, follow different migration paths than the dissolved contaminants in the groundwater.

- Improved access to the subsurface that reduces cost and increases data density and improved methods for sampling groundwater are needed. Specifically, drilling costs with existing technology reduce the number of wells that can be drilled for characterization. New methods are needed for discrete-depth sampling of groundwater from both existing wells and during installation of new wells (Technology Need RL-SS25).

Functional Performance Requirements: The techniques applied or information that is obtained must delineate contamination distribution such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project. The information must provide a better understanding of current conditions, and the ability to assess potential future conditions for near- and long-term scenarios.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with delineating groundwater plumes is needed in the FY00 to FY04 time frame to meet these objectives.

Problem Description: This need falls under the Groundwater Technical Element within the S&T Endeavor. The Groundwater Technical Element is intended to address and resolve scientific issues related to understanding the role of groundwater in the overall migration of

contaminants from the Hanford Site. The objective of the Groundwater Technical Element is to enhance protection of the Columbia River and its environs by 1) determining the existing distributions of contaminants with particular emphasis on 3D distribution, especially at the interfaces with the vadose zone and the river, and 2) enhancing the understanding of geological, chemical, geochemical, and hydrologic controls for future movement of contaminants. Detection of contaminants in groundwater monitoring wells underlying tanks, cribs, landfills, and other sources has often been the first indication of releases and migration. Understanding the flux and dynamics of vadose-capillary fringe-groundwater contaminant transfer and plume migration in three dimensions is critical to reconstructing vadose zone transport. On a larger scale, transport processes in groundwater control migration to extraction wells or surface water bodies (e.g., the Columbia River), define future risk scenarios, and affect the potential for optimized cleanup. An implicit goal of this research is to provide sufficient knowledge and data and identify existing and new S&T for input to DOE's decision-making process for Hanford Site cleanup.

This technical element provides the information, analytic capabilities, and understanding required for improving the technical basis for assessments of Hanford Site impacts to groundwater resources and the Columbia River. Groundwater represents an important portion of the potential exposure path and is the link between the source/vadose system and receptors at a well or the river. The technical scope of the groundwater element complements that of the vadose zone element by extending the characterization work into the saturated sediments under the Hanford Site. The saturated zone includes the capillary fringe, the unconfined aquifer, aquitards, and uppermost confined aquifers. The technical scope of the groundwater element also complements that of the river element by providing input to contaminant flux to the river and other interactions between the groundwater and Columbia River. Major topics include 1) the distribution of contamination within the saturated sediments; 2) the hydrology, geology, geochemistry, and microbiology of the saturated zone; 3) groundwater flow and transport of contamination; and 4) numerical models that depict the movement of water and contaminants.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: The structure of the regional plume for highly and moderately mobile contaminants is not fully defined and, thus, there is a limited scientific basis for collecting and representing geologic and hydrologic data over a variety of scales. The structure and development of the regional groundwater plumes is critical to estimating inventory of contaminants in groundwater for sitewide assessments and providing critical data to support sitewide groundwater modeling and its integration into the SAC being developed as part of the GW/VZ Integration Project. This plume structure also provides information about controlling hydrogeology and is critical to calibrating and documenting the quality/ performance of numerical models. In addition, hydrogeological characterization at multiple scales is needed to understand and predict flow and contaminant transport at the Hanford Site.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The information generated to address this need will provide high-quality estimates of contaminant position and behavior. Precise understanding the location of contaminant plumes is the most important basis for efficient and optimized remedial actions. If this need in not filled, such actions will need to be implemented to allow for more uncertainty – this uncertainty often results in more expensive and inefficient designs with more collateral environmental damage during construction and operation. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. The activity that this need supports will also be used to support development of the SAC as part of the GW/VZ Integration Project. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.3.3 Understand, Quantify and Develop Descriptions of Biogeochemical Reactions and Interactions Between Contaminants of Concern and Aquifer Sediments to Describe Biochemical Reactive Transport (RL-SS34)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand, quantify, and develop descriptions of biogeochemical reactions and interactions between contaminants of concern and aquifer sediments to describe biochemical reactive transport.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of

water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This need focuses on the reactions and interactions between contaminants and aquifer sediments. The primary technical gap is an insufficient understanding of these processes at the Hanford Site in terms of quantifying and parameterizing the processes for use in reactive transport modeling and to determine appropriate conceptual models. Biogeochemical reactions may result in either enhanced contaminant mobility, degradation (natural attenuation), or fixation in the unconfined aquifer. An understanding of these fundamental processes is needed to predict the long-term behavior of contaminants as they enter the unconfined aquifer and during transport along the groundwater flow path to the river. The need for reactive transport modeling has been pointed out by several recent peer reviews at the Hanford Site, one for the RPP vadose zone contamination issue and more recently for the Hanford Sitewide groundwater model. Specific needs to address this technical gap include the following:

- Mobility of transuranic (TRU) radionuclides (especially Np-237) in the groundwater, including the potential for complexation with DNAPL and the potential for colloid formation and transport.

- Information is needed to determine and quantify reactions such as biodegradation and interactions with aquifer sediments that impact the fate of dissolved DNAPL such as carbon tetrachloride in the groundwater.

- Techniques are needed to measure chemical, physical, and biological reactions and interactions in the aquifer and parameterize these measurements for use in models. Additionally, appropriate model formulations of these reactions and interactions are needed such that they can be incorporated into fate and transport models.

- Information is needed to understand the relationship between geochemical reactions and hydrogeological properties that affect transport in the aquifer.

- Descriptive kinetic and thermodynamic information for reactions and interactions in the aquifer based on key biogeochemical and hydrochemical reactions that control the fate and transport of contaminants in the groundwater are needed. Specific information needed includes the following. The speciation and complexation of contaminants interest in the aquifer is needed (Science Need RL-SS23-S). Information is needed to understand the reactions that will affect the binding of contaminants in solution on secondary mineral surfaces, and on primary phases (Science Need RL-SS24-S). The reaction rates and the key reaction steps that control the speed with which a contaminant changes chemical form

(e.g., speciation, complexation) and/or interacts with the surfaces of secondary minerals need to be quantified (Science Need RL-SS26-S). An understanding of the effect of coupled abiotic and biogeochemical reactions for which independent rates of reaction are known on contaminant form (e.g., speciation/complexation) is needed (Science Need RL-SS27-S). As is relevant to the fate and transport of carbon tetrachloride, information is needed to understand and quantify the rates of degradation reactions of naturally occurring organic matter and synthetic organic compounds that supply energy to subsurface biological consortia that participate in dechlorination of halogenated solvents (Science Need RL-SS32-S).

- Information is needed determine the chemical form and mobility of DNAPLs such as chlorinated solvents in the aquifer (Science Need RL-SS25-S).

- Information is needed to understand which secondary minerals form as colloids in groundwater, the importance of biosorption, the nature of the chemical interactions between contaminants of interest and the surfaces of inorganic and organic colloids, and the effect of colloids on contaminant transport at the Hanford Site (Science Need RL-SS28-S).

- Model formulations are needed for the chemistry and physics that describe the dispersal and longevity of subsurface contaminant plumes for site conditions, contaminant chemistry and reactivity, and hydraulic properties at the Hanford Site (Science Need RL-SS31-S).

- Techniques are needed to use readily measured chemical analogues (similar group, charge, ionic size) to contaminants of interest to assess the behavior of difficult-to-measure contaminants in the Hanford Site subsurface (Science Need RL-SS35-S).

- Evaluation of naturally occurring microbial communities in the groundwater and their impact on radionuclide and metal mobility is needed to understand current and predict future migration of contaminants.

The use of site-specific media (appropriate Hanford Site groundwater and sediments) is essential for all laboratory testing involved in acquiring the above information. Also, care must be taken to acquire “undisturbed” sediment samples to avoid altering the chemical reactivity of the natural materials.

Functional Performance Requirements: The techniques applied or information that is obtained must describe and quantify reactions and interactions between contaminants of concern and aquifer sediments such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project. The information must provide a better understanding of current conditions, and the ability to assess potential future conditions for near- and long-term scenarios.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with reactions and interactions in the aquifer is needed in the FY00 to FY04 time frame to meet these objectives.

Problem Description: This need falls under the Groundwater Technical Element within the S&T Endeavor. The Groundwater Technical Element is intended to address and resolve scientific issues related to understanding the role of groundwater in the overall migration of contaminants from the Hanford Site. The objective of the Groundwater Technical Element is to enhance protection of the Columbia River and its environs by 1) determining the existing distributions of contaminants with particular emphasis on 3D distribution, especially at the interfaces with the vadose zone and the river, and 2) enhancing the understanding of geological, chemical, geochemical, and hydrologic controls for future movement of contaminants. Understanding the flux and dynamics of vadose-capillary fringe-groundwater contaminant transfer and plume migration in three dimensions is critical to reconstructing vadose zone transport. On a larger scale, transport processes in groundwater control migration to extraction wells or surface water bodies (e.g., the Columbia River), define future risk scenarios, and affect the potential for optimized cleanup. An implicit goal of this research is to provide sufficient knowledge and data and identify existing and new S&T for input to DOE's decision-making process for Hanford Site cleanup.

This technical element provides the information, analytic capabilities, and understanding required for improving the technical basis for assessments of Hanford Site impacts to groundwater resources and the Columbia River. Groundwater represents an important portion of the potential exposure path and is the link between the source/vadose system and receptors at a well or the river. The technical scope of the groundwater element complements that of the vadose zone element by extending the characterization work into the saturated sediments under the Hanford Site. The saturated zone includes the capillary fringe, the unconfined aquifer, aquitards, and uppermost confined aquifers. The technical scope of the groundwater element also complements that of the river element by providing input to contaminant flux to the river and other interactions between the groundwater and Columbia River. Major topics include 1) the distribution of contamination within the saturated sediments; 2) the hydrology, geology, geochemistry, and microbiology of the saturated zone; 3) groundwater flow and transport of contamination; and 4) numerical models that depict the movement of water and contaminants.

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VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of these processes at the Hanford Site in terms of quantifying and parameterizing the processes for use in reactive transport modeling and to determine appropriate conceptual models. Biogeochemical reactions may result in either enhanced contaminant mobility, degradation (natural attenuation), or fixation in the unconfined aquifer. An understanding of these fundamental processes is needed to predict the long-term behavior of contaminants as they enter the unconfined aquifer and during transport along the groundwater flow path to the river for both site-specific assessments as well as to provide support for parameters used in the SAC.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None

Consequences of Not Filling Need: If this need is not filled, baseline information will be used that may not provide an appropriate description of important reactions and interactions related to contaminant transport. Thus, there will be more uncertainty in the technical basis used for decisions. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. The activity that this need supports will also be used to support development of site-specific assessments as well as the SAC as part of the GW/VZ Integration Project. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.3.4 Technologies to Quantify the Flux of Contaminant from Hanford Groundwater to the Columbia River (RL-SS35)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Technologies to quantify the flux of contaminant from Hanford groundwater to the Columbia River.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This need focuses on the delivery of contaminants from the groundwater to the river. Reexamination of boundary conditions and boundary fluxes was a key recommendation of the recent peer review of the Hanford Sitewide groundwater model. The necessary technologies and approaches focus on the distal portion of the Hanford Site groundwater plume. Information collected will provide robust information on contaminant releases and provide a sensitive system for monitoring the arrival of contaminants. This technical approach minimizes the artifacts associated with changing river stage and will improve the groundwater release estimates used in the Hanford Sitewide groundwater model and its integration into the SAC and enhance stakeholder credibility.

Specific issues that need to be addressed to resolve this technical gap include techniques to measure overall contaminant fluxes from the groundwater to the river. The techniques should be designed so that they will not be significantly impacted by the transient effects and measurement artifacts associated with the river stage. They are needed to provide a better estimate of contaminant flux. These techniques should provide representative monitoring data and depth discrete information on contaminant distribution and flux in the aquifer near the river. Additionally, techniques are needed to assess the representativeness and quality of these depth discrete groundwater monitoring methods. These needs focus on determining how contaminants discharge to the river – along the shoreline, in the bed of the river, and how far out into the river – and determining how these discharges are affected by daily and seasonal variations of river stage.

Functional Performance Requirements: The techniques applied or information that is obtained must quantify the contaminants flux to the river such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project. The information must provide an accurate understanding of current conditions, and the ability to assess potential future conditions for near- and long-term scenarios.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with quantifying contaminant flux is needed in the FY00 to FY01 time frame to meet these objectives.

Problem Description: This need falls under the Groundwater Technical Element within the S&T Endeavor. The Groundwater Technical Element is intended to address and resolve scientific issues related to understanding the role of groundwater in the overall migration of contaminants from the Hanford Site. The objective of the Groundwater Technical Element is to enhance protection of the Columbia River and its environs by 1) determining the existing distributions of contaminants with particular emphasis on 3D distribution, especially at the interfaces with the vadose zone and the river, and 2) enhancing the understanding of geological, chemical, geochemical, and hydrologic controls for future movement of contaminants. Detection of contaminants in groundwater monitoring wells underlying tanks, cribs, landfills, and other sources has often been the first indication of releases and migration. Understanding the flux and dynamics of vadose-capillary fringe-groundwater contaminant transfer and plume migration in three dimensions is critical to reconstructing vadose zone transport. On a larger scale, transport

processes in groundwater control migration to extraction wells or surface water bodies (e.g., the Columbia River), define future risk scenarios, and affect the potential for optimized cleanup. An implicit goal of this research is to provide sufficient knowledge and data and identify existing and new S&T for input to DOE's decision-making process for Hanford Site cleanup.

This technical element provides the information, analytic capabilities, and understanding required for improving the technical basis for assessments of Hanford Site impacts to groundwater resources and the Columbia River. Groundwater represents an important portion of the potential exposure path and is the link between the source/vadose system and receptors at a well or the river. The technical scope of the groundwater element complements that of the vadose zone element by extending the characterization work into the saturated sediments under the Hanford Site. The saturated zone includes the capillary fringe, the unconfined aquifer, aquitards, and uppermost confined aquifers. The technical scope of the groundwater element also complements that of the river element by providing input to contaminant flux to the river and other interactions between the groundwater and Columbia River. Major topics include 1) the distribution of contamination within the saturated sediments; 2) the hydrology, geology, geochemistry, and microbiology of the saturated zone; 3) groundwater flow and transport of contamination; and 4) numerical models that depict the movement of water and contaminants.

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VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of the horizontal location, vertical structure, and location of the groundwater contamination as it approaches and enters the Columbia River. This information is necessary to document the near-river transport path of contaminant plumes to the receptor and will be used by the sitewide groundwater model and its integration into the SAC.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The information generated to address this need will provide high-quality estimates of contaminant flux and provide a sentinel (early warning) system for future contaminant arrival. The robustness and defensibility of the data will provide the basis for efficient and optimized remedial actions. If this need is not filled, such actions will need to be implemented to allow for more uncertainty – this uncertainty often results in more expensive and inefficient designs with more collateral environmental damage during construction and operation. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. The activity that this need supports will also be used to support development of site-specific assessments as well as the SAC as part of the GW/VZ Integration Project. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.4 RIVER TECHNICAL ELEMENTS

Table B-4. River Element Index to Linked Needs.

RL-SS36	Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River
RL-SS37	Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment
RL-SS38	Understand, quantify, and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river
RL-SS39	Understand and provide means to quantify the impacts of river contamination on receptors

B.4.1 Provide Means to Integrate Regional-Scale Phenomena into Assessments of Contaminant Transport and Impacts Within the Columbia River (RL-SS36)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Provide means to integrate regional-scale phenomena into assessments of contaminant transport and impacts within the Columbia River.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The primary technical gap for this specific need is the lack of a quantitative understanding of the regional (watershed) factors that influence the distribution, transport, and chemical form of contaminants from Hanford Site operations on the Columbia River. Key factors include river flow parameters; sediment movement and sedimentation; water hardness, pH, and water temperature; the distribution of gravel, cobble, and silt/clay sediments within the Hanford Reach and downstream; and the redox status and acid-volatile sulfide contents of softbottom sediments in these areas. Although all of these factors are known or suspected to be important in determining contaminant movement and bioavailability, there is little capability to predict either (a) the responses of these factors to regional conditions or (b) the combined effects of these factors on contaminants.

The science gap to be filled by this need is a hierarchical series of models that define regional interrelationships with regard to their effects on contaminant mobility, distribution, and bioavailability. Specifically, these models include the following:

- A conceptual model that relates inputs to the Hanford Reach from upriver to the physical/chemical state of contaminants entering via groundwater, and thereafter affect transport. This model must also incorporate understanding of the biological relationships between contaminants and the nutrients for which they are analogues, as well as movement of background contaminants (e.g., heavy metals from Lake Roosevelt, fallout products in river sediments) into the Hanford Reach and downstream.

- A Geographic Information System visualization of the distribution of substrate conditions within the Hanford Reach to McNary Dam, and below.

- A semiquantitative model that will provide order-of-magnitude estimates of the effects on transport and bioavailability due to uncertainty in the key factors.

- A quantitative model that is capable of converting regional-scale phenomena (e.g., hydropower operations, El Niño weather patterns, cleanup of the Spokane River) into quantitative estimates of physical/chemical conditions pertinent to quantifying contaminant transport within the river system.

The technology gaps include development of tools to measure the primary contributors to contaminant mobility, distribution, and bioavailability in a cost-effective manner. These include the following:

- Hyporheic probes capable of operation in shallow and deep waters under a variety of current speeds and rapidly changing water depths
- Refined sediment, pore water, and water sampling tools capable of discrete sampling over short vertical distances
- Underwater visualization tools hybridized with accurate global positioning system to map substrates.

Functional Performance Requirements: The techniques applied or information that is obtained must provide an accurate understanding of current conditions and the ability to assess potential future conditions, near and long term, as they impact contaminant concentrations, form, transport, and bioavailability. In addition, the evaluation must allow for the differentiation between contaminant contributions from the Hanford Site and other sources (natural and/or anthropogenic). The information obtained must be applicable toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with regional-scale phenomena is needed in the FY00 to FY04 time frame to meet these objectives.

Problem Description: This need falls under the River Technical Element within the S&T Endeavor. The River Technical Element is intended to support and provide information necessary for an assessment of the effects of Hanford Site-derived materials and contaminants on the Columbia River environment, river-dependent life, and users of river resources. The objectives of the River Technical Element are to provide relevant and meaningful information to support remedial decisions and subsequent risk and system assessments, to guide ongoing and subsequent environmental surveillance programs, and to focus future iterations of the cumulative river assessment. Meeting the objectives will enhance protection of human health and the environment by providing scientifically defensible knowledge and data and identifying existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The scope of this technology need relates to information needs associated with background contaminant inputs, nutrient conditions, benthic conditions, and physical/chemical properties of the water and sediments that will form the basis for predicting the fate and transport of contamination entering this river environment from Hanford Site groundwater. These include spatial/temporal flow patterns, hardness, pH, temperature, DOC, nutrient load, and sediment load and characteristics entering the Hanford Reach; physical transport of water-phase and

particulate-phase contaminants in the Hanford Reach and downstream (as affected by hydropower operations downstream); and changes in bioavailability of the contaminants themselves. Interaction with the suspended load of the river, and with biological systems, is key to anticipating the fate of contaminants. Erosion and deposition patterns for the river are major topics for understanding where potential contaminant sinks are located, and where sensitive species and humans are at greatest potential threat of exposure. Understanding how the channel morphology and its distribution of sediments evolve (with time) is key to anticipating future conditions.

Credible conceptual and numerical models for processes occurring in this zone are crucial to 1) identifying impacts to the river's ecosystem and 2) quantifying risks to aquatic and human receptors. This zone encompasses near-river groundwater and infiltrated river water (bank storage), and the hyporheos (sediment pore water and biota immediately beneath the free-flowing stream). The Columbia River technical element scope includes the capability to provide information necessary to assess accurately and credibly the risk posed by Hanford Site contaminants to aquatic, terrestrial, and human receptors in the river environment.

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VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There currently is inadequate understanding of the relative importance of regional-scale phenomena relative to contaminant transport and bioavailability within the Hanford Reach and downstream, nor is there the quantitative capability to integrate these into useful models. This information is need to develop a numeric model of the river system that includes the critical processes and components necessary to conduct the assessments required to meet the objectives of the project.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: Without a predictive capability, decisions regarding impacts will be made on the basis of currently available data regarding conditions within the Hanford Reach and downstream. As demonstrated in the CRCIA study (DOE-RL 1998a), background inputs of contaminants as well as nutrients severely affects assessments of level of impact – heavy metal inputs from upriver of the Hanford Site may account for as much as 90% of the present impacts within the Hanford Reach. Furthermore, the concentrations of nutrients for which certain contaminants are analogues (e.g., calcium and strontium) can greatly affect biological uptake and transport, in some cases altering bioconcentration factors by as much as 3 to 4 orders of magnitude (Cushing et al. 1988). The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

Cushing, C. E., W. H. Rickard, and D. G. Watson, 1988, *Radionuclide Accumulation by Aquatic Biota Exposed to Contaminated Water in Artificial Ecosystems Before and After Its Passage Through the Ground*, NUREG/CR-5047, U.S. Nuclear Regulatory Commission Washington, D.C.

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.4.2 Provide Methodology to Relate Information Derived from Sitewide-Scale Groundwater Flow Modeling to the Various Scales Associated with Assessing Impacts in the River Environment (RL-SS37)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Provide methodology to relate information derived from sitewide-scale groundwater flow modeling to the various scales associated with assessing impacts in the river environment.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The technical gap associated with this need involves the means by which contaminant transport information derived from groundwater flow models (see RL-SS35) can be used when conducting impact assessments for various elements of the river system. The problem involves relating the spatial and temporal scales associated with a Pasco Basin groundwater transport model to the scales associated with assessing impacts to sensitive habitat and individual receptors. New methods are needed to establish credible estimates for contaminant characteristics at exposure sites in the river, when using the output from groundwater transport models. Organisms potentially exposed to groundwater-derived contaminants may occupy one or more microhabitats that will significantly affect their exposure to groundwater. Thus, benthic invertebrates such as larval insects may be exposed to pure groundwater in some cases, and nearly pure river water in others (e.g., Hope and Peterson 1996). Because river water over much of the Hanford Reach does not contain contaminants in concentrations sufficient to put organisms or humans at risk (in contrast to groundwater), the differences in assessment of impact can be dramatic (DOE 1996).

Specific aspects of research to address this technical gap include the following:

- Developing the modeling capabilities to quantify the changes in groundwater characteristics that take place in the zone of interaction between the aquifer and the river.

- Developing the modeling capabilities to characterize the flow path of water within the zone of interaction, which is strongly influenced by river stage fluctuations.

- Developing the algorithms for estimating contaminant concentrations in the river environment (using the output from groundwater flow models – see RL-SS38) that consider the potential physical and chemical changes that may occur in the zone of interaction. This model will provide the capability to convert a broad-scale groundwater flux into a spatially distributed set of concentrations in three dimensions as the flux enters the river environment. This model will reflect the benthic substrate diversity, river flow, and river physico-chemical characteristics (see RL-SS36) necessary to provide concentration estimates that reflect bioavailability as well as habitat specificity.

Functional Performance Requirements: The techniques applied or information that is obtained must provide an accurate understanding of current conditions over time and the ability to assess potential future conditions, near and long term. In addition, the evaluation must allow for the differentiation between contaminant contributions from the Hanford Site and other sources (natural and/or anthropogenic). The information obtained must be applicable toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with contaminant flux is needed in the FY00 to FY05 time frame to meet these objectives.

Problem Description: This need falls under the River Technical Element within the S&T Endeavor. The River Technical Element is intended to support and provide information necessary for an assessment of the effects of Hanford Site-derived materials and contaminants on the Columbia River environment, river-dependent life, and users of river resources. The objectives of the River Technical Element are to provide relevant and meaningful information to support remedial decisions and subsequent risk and system assessments, to guide ongoing and subsequent environmental surveillance programs, and to focus future iterations of the cumulative river assessment. Meeting the objectives will enhance protection of human health and the environment by providing scientifically defensible knowledge and data and identifying existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The scope of this technology need encompasses the groundwater-river interface as it relates to the fate and transport of groundwater contamination entering the river environment. These include factors that modify the physical/chemical form and concentration of groundwater-borne contaminants within the zone of influence of the Columbia River up to the point that they enter the river proper.

Key topics in this need include mixing (dilution) with river water, effects of geochemical conditions of the sediment and river water on contaminant physical and chemical state, the influence of preferential pathways (e.g., cobble vs. silt-clay sediments), and the effects of spatial heterogeneity in hyporheic sediment composition on contaminant concentrations entering the river. Credible conceptual and numerical models for processes occurring in this zone are needed to quantify accurately 1) impacts to the river's ecosystem and 2) risks to human receptors.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There are insufficient means to translate groundwater contaminant flux estimates into information at the scale of biological exposures that are necessary to estimate impacts from groundwater contaminants entering the river.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: By not filling this technical gap, a high degree of uncertainty will be attached to impact and risk assessments associated with river-related receptors. The uncertainties introduced in converting groundwater flux information into biological exposures are large, and may cover several orders of magnitude (DOE 1996). In the absence of this technology, a variety of conservative estimations have been used at the Hanford Site that may greatly inflate (DOE-RL 1998a) or underestimate (DOE-RL 1993) risks. The uncertainty in decisions about cleanup and impact may therefore be large. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

DOE-RL, 1993, *Columbia River Impact Evaluation Plan*, DOE/RL-92-28, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Hope, S. J. and R. E. Peterson, 1996, *Chromium in River Substrate Water and Adjacent Groundwater: 100-D/DR Area, Hanford Site, Washington*, BHI-00778, Bechtel Hanford, Inc., Richland, Washington.

B.4.3 Understand, Quantify, and Develop Descriptions of Transport and Transformation of Groundwater-Derived Contaminants of Concern in the River (RL-SS38)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
___ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
___ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand, quantify and develop descriptions of transport and transformation of groundwater-derived contaminants of concern in the river.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The primary technical gap associated with reactions and interactions between contaminants and sediments in the river and bank-storage region involves insufficient understanding of these processes at the Hanford Site in terms of quantifying and parameterizing the processes for use in the development and application fate and transport. An understanding of these fundamental processes is needed to predict the fate and transport of contaminants into and through the river. Specific issues that need to be addressed to resolve this technical gap include the following:

- The chemical, physical, and biological reactions and transformations that occur within the bank storage region (i.e., zone of interaction between the near-river aquifer and vadose zone sediments that are affected by river stage fluctuations) can greatly affect the form, concentration, and spatial/temporal distribution of contaminants moving within the surface water system. Bank storage clearly delays downstream transport of water-borne contaminants, and may prolong aquatic biological exposures in the nearshore environments. In addition, bank storage may enhance exposures of terrestrial species to contaminants not otherwise found in the groundwater at these regions (Brandt et al. 1993).

- Physics-based transport models (hydraulic, sediment, contaminant) are needed to represent the movement of contaminants into and through the river environment.

- Numerical models are needed that incorporate the chemical, physical, and biological reactions and interactions in the river for contaminants in aqueous phase (dissolved species), colloid phase, and sediment phase into the physics-based transport models based on hydraulics and sediment transport.

- Models are needed to predict changes in the bioavailability, bioaccumulation, and biodegradation of contaminants for the development of representative biological transport models, based on the numerical models identified above.

- Techniques/equipment/instrumentation are desired to measure chemical, physical, and biological parameters in the bank-storage region and the river to parameterize, validate, and verify these models.

Functional Performance Requirements: The techniques applied or information that is obtained must provide an accurate understanding of current conditions over time and the ability to assess potential future conditions, near and long term. In addition, the evaluation must allow for the differentiation between contaminant contributions from the Hanford Site and other sources (natural and/or anthropogenic). The information obtained must be applicable toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with reactions and interactions is needed in the FY00 to FY05 time frame to meet these objectives.

Problem Description: This need falls under the River Technical Element within the S&T Endeavor. The River Technical Element is intended to support and provide information necessary for an assessment of the effects of Hanford Site-derived materials and contaminants on the Columbia River environment, river-dependent life, and users of river resources. The objectives of the River Technical Element are to provide relevant and meaningful information to support remedial decisions and subsequent risk and system assessments, to guide ongoing and subsequent environmental surveillance programs, and to focus future iterations of the cumulative river assessment. Meeting the objectives will enhance protection of human health and the environment by providing scientifically defensible knowledge and data and identifying existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The scope of this technology need relates to information needs associated with the fate and transport of groundwater-based contamination once it enters the river environment. These include understanding the contaminant characteristics (type, nature, concentration, decay/attenuation qualities) as they relate to the physical and chemical conditions of the river as it enters the Hanford Reach as developed in RL-SS36. Understanding the interactions of the contaminants with the dissolved organic matter, suspended load, and biological systems of the river, as well as the role of bank storage in altering the timing, chemical nature, and concentration of contaminants as they move through the river system, are key to accurately predicting the fate of contaminants.

Key topics in this zone include the following:

- Mixing processes within the river
- Geochemical conditions of the water and sediments that affect bioavailability and transport
- Life history descriptions and parameters for key species relative to quantification of exposure
- Food web structure and biological transport parameters for key species and habitats
- Bank storage and physical/chemical transformations within the river bank
- Numerical river flow and sedimentation models that account for the daily fluctuating hydrograph of the managed river system.

Credible conceptual and numerical models for processes occurring in this zone are crucial to 1) identifying impacts to the river's ecosystem and 2) quantifying risks to aquatic and human receptors.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of reactions and interactions of contaminants and sediments at the Hanford Site in terms of quantifying and parameterizing the processes for use in reactive transport modeling and for determining appropriate conceptual models. An understanding of these fundamental processes is needed to predict the fate and transport of contaminants in the river.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: The current state of river transport modeling currently has biological transport, physical transport, and physical/chemical state of the contaminants in an uncoupled configuration. Bank storage is neglected as a prolonged source of contaminant exposure, and neither its modulating capacity nor ability to diffuse contaminated surface water into the surrounding terrestrial biota has not been addressed. Consequently, decisions regarding impacts downstream from groundwater plumes are uncertain, and our ability to predict future effects accurately is weakened. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

Brandt, C. A., C. E. Cushing, W. H. Rickard, N. A. Cadoret, R. Mazaika, and B. L. Tiller, 1993, *Biological Uptake of 300-FF-5 Operable Unit Contaminants*, WHC-SD-EN-TI-122, Westinghouse Hanford Company, Richland, Washington.

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

B.4.4 Understand and Provide Means to Quantify the Impacts of River Contamination on Receptors (RL-SS39)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-10 and ER-18: MLLW GW 100/200 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Understand and provide means to quantify the impacts of river contamination on receptors.

Need/Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The primary technical gap associated with the impacts of river contamination on receptors is that there is an insufficient understanding of the human, ecological, cultural, and socio-economic impacts of contaminants that reach the river and the relationship between contaminants entering the river and behavioral impacts on culture and socio-economics. Currently, standard impact assessment practice involves comparing estimated exposures of individual organisms to a lowest-observed-effects level toxicological benchmark, such as behavioral change or tissue-level alterations. Regulated exposure levels are sometimes also based on no-observed-effects levels, which have a number of inadequacies aside from their level of biological resolution (Chapman et al. 1996). In either case, however, the interest of regulation and impact assessment is not at the individual or sub-individual level, but at the level of the population and its properties, such as abundance, health, and productivity. There is a need to develop consistent metrics upon which to determine impacts (human, ecological, cultural, socio-economic) that are useful in the decision-making process and reflective of appropriate level of organization of the focus receptor groups. The development of consistent metrics includes the quantitative capability for translating an individual-level dose response into the impact metrics that are important to regulators and stakeholders, including the general public (see Levin et al. 1989, Newman and Jagoe 1996).

Specific technical gaps associated with the development of impact metrics include the following:

- Appropriate toxicological benchmarks need to be developed for contaminants likely to enter the river, involving species important from ecological and human perspectives. This need includes information to determine the impacts from diverse contaminant mixtures, e.g., accounting for potential synergistic/antagonistic effects.

- The ecological interactions and processes within the affected system need to be understood such that a reasonable prediction of higher order effects (e.g., at the population level) can be made based on toxicological benchmarks (e.g., translating a genetic-level toxicological benchmark into a population survival/productivity change effect).

- Information is needed to translate ecological impacts into cultural and socio-economic impacts.

Functional Performance Requirements: The techniques applied or information that is obtained must provide an accurate understanding of current conditions over time and the ability to assess potential future conditions, near and long term. In addition, the evaluation must allow for the differentiation between contaminant contributions from the Hanford Site and other sources (natural and/or anthropogenic). The information obtained must be applicable toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with impacts of contamination is needed in the FY00 to FY05 time frame to meet these objectives.

Problem Description: This need falls under the River Technical Element within the S&T Endeavor. The River Technical Element is intended to support and provide information necessary for an assessment of the effects of Hanford Site-derived materials and contaminants on the Columbia River environment, river-dependent life, and users of river resources. The objectives of the River Technical Element are to provide relevant and meaningful information to support remedial decisions and subsequent risk and system assessments, to guide ongoing and subsequent environmental surveillance programs, and to focus future iterations of the cumulative river assessment. Meeting the objectives will enhance protection of human health and the environment by providing scientifically defensible knowledge and data and identifying existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The scope of this technology need includes effects of contaminant exposures on the biota, cultures, and socioeconomics associated with the Columbia River.

Key issues in this technical area include developing credible conceptual and numerical models for 1) identifying toxicological impacts to the river's ecosystem, and 2) quantifying meaningful effects relative to ecological attributes and human receptors. Key information needs include identifying 1) toxicological benchmarks for regional species of concern for contaminants of concern, 2) definitions of desired metrics to assess impacts, 3) effects of complex contaminant mixtures, and 4) translational models for converting toxicity into impact metrics for human and ecological endpoints.

PBS No.	WBS No.	TIP No.
VZ01	1.4.10.1.7.11.03	

Justification for Need:

Technical: There is an insufficient understanding of the human, ecological, cultural, and socio-economic impacts of contaminants that reach the river and the relationship between contaminants entering the river and behavioral impacts on culture and socio-economics. This information is necessary to accurately and credibly assess of risk posed by Hanford Site contaminants to aquatic, terrestrial, and human receptors in the river environment.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998a).

Other: None.

Consequences of Not Filling Need: Without the information described in this need, there will be more uncertainty in the technical basis for quantifying the impacts of river contamination on receptors. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector).

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

Chapman, P. M., R. S. Caldwell, and P. F. Chapman, 1996, *A Warning: NOECs are Inappropriate for Regulatory Use*, Environ. Toxicol. Chem.

DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Levin, S. A., M. A. Harwell, J. R. Kelly, and K. D. Kimball, eds., 1989, *Ecotoxicology: Problems and Approaches*, Springer-Verlag, New York.

Newman, M. C. and C. H. Jagoe, eds., 1996, *Ecotoxicology, A Hierarchical Treatment*, CRC Press, Boca Raton, Florida.

B.5 INVENTORY TECHNICAL ELEMENTS

Table B-5. Inventory Element Index to Linked Needs.

RL-SS40	Provide a method to develop mass balance (i.e., holistic) inventory estimates
RL-WT056-S	Half-Lives of Se-79 and Sn-126
RL-WT041-S	Radionuclide Partitioning
RL-WT052-S	Characterization of Organic Species in Waste Feed to LAW and High-Level Waste (HLW) Treatment Facilities
RL-WTNEW04	Uncertainty Estimation of Hanford Best Basis Toxic Waste Inventory, Concentration, Phase and Waste Type
RL-WT01	Technetium-99 Analysis in Hanford Tank Waste and Contaminated Tank Farm Areas
RL-WT065	Direct Inorganic and Organic Analyses of High-Level Waste
RL-SS42	Provide method for more accurate estimates of waste constituent release rates and modes from waste
RL-WTNEW02	Radionuclide Source Term from Tank Residuals

B.5.1 Provide a Method to Develop Mass Balance (i.e., Holistic) Inventory Estimates (RL-SS40)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-03: MLLW Soils, ER-04: LLW Soils 100/ 300 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Provide a method to develop mass balance (i.e., holistic) inventory estimates.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Currently, there is not a full inventory data set for all of the contaminants of interest for all of the waste sites of interest at the Hanford Site. These data are needed as input to the SAC, which is a suite of tools and data that will be used to assess the cumulative effects of Hanford Site operations and remediation on the Columbia River and river-supported life. Based on scoping studies currently underway within the SAC, key radionuclide and chemical contaminants of most concern for assessing cumulative impacts will be identified. From previous experience, we know there will be gaps in inventory data for many of these contaminants, and that these gaps will contribute significantly to uncertainty in the final assessment.

There is a desire within the stakeholder and Tribal Nation community that all contaminants be included in the inventory model. The purpose of such an exhaustive model would be to ensure that all wastes and all associated impacts would be quantified. It has been suggested that if a specific radionuclide or chemical were not identified as a key contaminant, then it could be lumped with other non-key contaminants and carried throughout the transport and impact estimation process. The non-key contaminants would be represented as a lumped inventory; a lumped transport plume; and a lumped human, ecological, cultural, and socioeconomic consequence. However, once a waste-site-specific assessment has been undertaken, the multiple waste types and variety of waste site locations of a Hanford Site assessment make the lumping of inventory, release, transport, and impact assessment difficult if not intractable. Consequently, the initial inventory module for the SAC will focus on key radionuclides and chemicals.

The desire of the stakeholder community and Tribal Nations to track all contaminants would be an extension of the initial inventory module and the initial system assessment. Lumping the inventory, its migration and fate, and its impact assessment may not be tractable because of the distributed nature of the multiple-source problem and the desire to represent the uncertainty of disposal on a waste site-by-waste site basis. Clearly, a single simulation could not be conducted and the results scaled for individual waste sites (e.g., scaled up for some and down for others) to maintain a mass balance of the inventory.

Currently, individual projects use conservative bounding inventory estimates, but use of this approach is not realistic for a sitewide assessment. Use of a conservative or bounding inventory estimate by an individual project can be useful when releases are shown to result in deminimus or low consequences. Projects (e.g., RPP) are beginning to address a spectrum of inventory issues (e.g., inventory to be separated into high- and low-level fractions, low-level waste disposal, and the disposal of secondary waste streams from separations and vitrification plants). With these multiple drivers, they too can rely less on a conservative or bounding inventory and need a realistic inventory estimate characterized by a mean and standard deviation. Hence, the primary technical gap is the need to develop a mass balance (i.e., holistic) inventory estimate that results in realistic inventories and estimates of uncertainty. This estimate needs to have a scientifically credible basis such as use of process chemistry and historical records to estimate release quantity, waste chemistry, release location, and time of release from Hanford Site processes to soil sites.

Specific needs include the following:

- Definition of post-closure Hanford Site waste site groupings that can be traced to the processes from which wastes were generated and discharged (DOE-RL 1997). These groupings become the basis for developing realistic estimates of waste inventory in the environment over space and time.

- Enhancement of the "Hanford Defined Waste" (HDW) model (Agnew et al. 1997) using process chemistry is needed to estimate the range of probable waste composition, quantities, release locations, and timing of releases. This process chemistry information includes improved partitioning models and tank inventory models (Science Need RL-WT041-S). The

process chemistry and tank inventory models are needed by the RPP to support development of pretreatment processes for waste immobilization and disposal. However, radionuclide and chemical partitioning within tank waste will also aid in the determination of soil column inventories, both for planned releases to cribs and trenches and unplanned historical releases (i.e., past leaks). An improved understanding of Tc-99 and Se-79, for example, will improve estimates of releases to soils for these contaminants, both of which are important in performance assessments.

- Expansion and enhancement of the HDW model are needed to represent non-tank waste and to identify clearly crib and trench discharges of tank wastes. All past-practice liquid discharge sites ready for closure including ponds, cribs, ditches, reverse wells, and specific retention trenches are Environmental Restoration sites (DOE-RL 1999a). The chemical separations conducted in the canyon buildings yielded waste streams that were discharged directly to ditches and cooling ponds, chemical sewers, and cribs. Some resulted in significant plumes (e.g., tritium) that are routinely used for model history matching. Because they were not tank wastes, they are not included in the current HDW model. Additional waste streams and inventories not accounted for in the existing HDW model that need to be added are the Plutonium Finishing Plant (PFP) building, plutonium/uranium extraction (PUREX) tunnels, solid waste burial grounds, graphite cores from production reactors, ancillary piping, and residues in the canyon buildings. In addition to these new wastes, the original tank wastes discharged to cribs and trenches and reported in the HDW model need to be identified with specific cribs and trenches instead of being reported as global crib discharges. As in the original HDW model, the revised model shall provide a probabilistic representation of the inventory.

- Determination of Se-79 and Sn-126 half-lives for which conflicting values have been reported is needed for inventory and system/performance assessment purposes (Science Need RL-WT056-S). Se-79 is important for long-term protection of the environment. Sn-126 is important in the protection of inadvertent intruders. For purposes of the system assessment inventory, measurement of the half-lives within +/- 50% is sufficient. Other projects require +/-10%.

- Estimation of released waste inventory and uncertainty for H-3, Co-60, Tc-99, Sr-90, Cs-137, I-129, uranium, Np-237, plutonium, americium, sodium, aluminum, chromium, carbon tetrachloride, OH^-, NO_3^-, complexants, pH, density, ionic strength, heat load, water weight percent, water vapor pressure, and redox state, as needed. This first listing of inventory needs is a result of an initial review of radionuclides and chemicals found to be significant in the assessment of both plateau and near-river waste sites. Coordination with RPP, which has a need to estimate uncertainty of Hanford Best Basis toxic waste inventory, concentration, phase, and waste type (Technology Need RL-WTNEW04), will be beneficial to multiple projects.

- Specific models for Tc-99, I-129, and tritium need to be established to transition from conservative to mass-balance models of inventory. The Tc-99 model is needed to reconcile Tc-99 inventory consistent with new mass balances being completed by the RPP in FY99. This model must also be able to reconcile inventory problems for Tc-99 uncovered from past work such as the Composite Analysis (Kincaid et al 1998), e.g., shipment of Tc-99 offsite

with uranium and underestimates of Tc-99 discharges to cribs receiving wastes from the uranium recovery campaign. Likewise, a model for I-129 is needed to reconcile inventory completeness issues discovered from past work on the Composite Analysis. The iodine model is complex because it will include aspects of atmospheric emissions, stack scrubbers, scrubber regeneration, scrubber failure, and scrubber disposal. A model for tritium is needed to help benchmark the overall inventory model and the overall vadose zone and groundwater models that are essential components of the SAC. Future efforts may uncover additional contaminants for which selected models may be needed and will be added to this need in the future as required.

- An accurate, robust production laboratory method for the measurement of Tc-99 concentration in Hanford Site waste tank matrices and in soils from the vadose zone surrounding the tanks is needed (Technology Need RL-WT01). The method must provide a high level of confidence in the TC-99 concentrations because the data are important in risk-based assessments. The development of this method is needed so that data can be obtained to benchmark the process chemistry, release, vadose zone, and groundwater models.

- Characterization methods to determine organic species in tank waste are needed (Science Need RL-WT052-S). There are two aspects to this need: 1) the speciation of the organic compounds determines the complexing characteristics of the organic compound; the complexing nature can affect the behavior of other waste components and can affect the mobility of specific components in the waste and in the vadose zone, and 2) measurement of the amount of certain *Resource Conservation and Recovery Act* (RCRA) and *Toxic Substances Control Act of 1976* (TSCA) organic compounds in the waste is important to risk-based assessments.

- Direct methods for inorganic and organic analyses of high-level waste would reduce turn-around time, waste production, and worker exposure (Technology Need RL-WT065), which would in turn reduce costs. Lower costs for characterization would make it possible to characterize more of the waste tanks and the contaminated zones around and beneath the tanks. The additional data could also be used to improve the benchmarking of the models.

Functional Performance Requirements: The techniques applied or information that is obtained must estimate contaminant inventory such that the information can be applied toward the conceptual models, fate and transport numerical models, site-specific assessments, and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with inventories is needed in the FY99 to FY01 time frame to meet the objective of the Integration Project to provide the Hanford Site with a sitewide composite analysis within 5 years. Such an analysis will not only satisfy the DOE requirement for active and near-term planned disposal and remediation action decisions, but will also inform DOE-Office of River Protection (ORP) on the cumulative impacts of decisions bearing on tank waste recovery and tank residuals.

Problem Description: This need falls under the Inventory Technical Element within the S&T Endeavor. Inventory is defined as the total quantity of radiological and chemical constituents used and created at the Hanford Site, and their distribution in facilities, waste disposal sites, the vadose zone, groundwater, and Columbia River ecosystem. The Inventory Technical Element is intended to address the need for estimates of radionuclide and chemical contaminants that have been or are expected to be released to Hanford Site's soil column. Such an inventory would represent the total amount of selected radionuclide and chemical constituents at the Hanford Site and their distribution among facilities, waste disposal sites, vadose zone, groundwater, and Columbia River. The objective of the Inventory Technical Element is to enhance protection of human health and environment by providing estimates of the location, amounts, concentrations, chemical form, and mobilization/release mechanisms of key inventory components, which provides the necessary input to sitewide subsurface system assessments. An implicit goal of this research is to provide scientifically defensible knowledge and data and identify existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The goals of the inventory technical element are largely twofold. First, a consistent approach and set of assumptions for providing information on waste site inventories across the Hanford Site needs to be established to ensure that a sitewide inventory data set is available for system-wide and project-specific impact assessments. Second, key chemical and radiological contaminants and soil sites need to be identified, and estimates of the amount of these key contaminants in different waste forms and storage/disposal areas (e.g., tanks, solid waste burial grounds, other) need to be validated.

A good understanding of inventory is key to a system assessment, because the potential groundwater and river contamination is proportional to the amount of radionuclides and chemicals that are disposed on Hanford Site and capable of migrating off the site. Technical information needed to determine inventory include 1) locations, amounts, and concentrations; 2) characteristics of the radionuclide or chemical compound; 3) mobilization and release mechanisms and rates; and 4) the change in inventory because of natural processes (e.g., decay), remediation activities, and Hanford Site operations. In addition to inventory estimates, mechanisms must be identified that result in release of the inventory from facilities into the vadose zone, unconfined aquifer, or the Columbia River. Because the long-term configuration of the waste inventory depends on future remediation and land-use decisions, a baseline estimate of end-state inventory distributions must be defined.

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Justification for Need:

Technical: Currently, there is not a full inventory data set for all of the waste sites and all operational areas at the Hanford Site. This data set is needed as input to the SAC, which is a suite of tools and data that allow the assessment of the cumulative effects of Hanford Site operations and remediation on the Columbia River and associated river-supported activities. Previous experience indicates that a lack of a method to provide a realistic estimate of

inventory adds substantial (i.e., an order of magnitude) uncertainty in the modeling results (DOE-RL 1999b).

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions. A sitewide Composite Analysis of all post-closure sources is required every 5 years under DOE Order 5820.2a (and draft DOE Order 435.1). Other sitewide assessments are needed by Environmental Restoration (ER) and RPP to fully understand the nature of competing alternatives (e.g., ER characterization and cleanup versus RPP tank waste recovery and stabilization).

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues. The CRCIA Part 2 (DOE-RL 1998a) guidance requires the assessment of human health, ecological health, and cultural and socioeconomic impacts. All of these societal health metrics are impacted by the broad support of stakeholders and Tribal Nations (e.g., common health exposure and dose scenarios are being adapted to include exposures typical of Native Americans). As these broad metrics are applied, a longer list of radionuclides and chemicals may be revealed as essential to the assessment.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

Assembly of a sitewide and comprehensive inventory will improve upon the existing capabilities (i.e., tank waste inventory) and provide several projects (and their associated wastes) with a consistent inventory for environmental impact statements, composite analyses, and site/waste-specific studies supporting the evaluation of alternate remediations.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment*. (Stakeholder and Tribal Nation concerns about the completeness and consistency of the assembly of inventory data and estimates are expressed in the CRCIA Part 2 document [DOE 1998a].)

Other: None.

Consequences of Not Filling Need: Completion of a first inventory model based on available data, process chemistry knowledge, and uncertainty principles is essential to any sitewide or system assessment. Currently, there is no single and consistent inventory for the discharges and disposals of radionuclides and chemicals to the surface and subsurface in the 100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, 300, 200 West, and 200 East Areas. This inventory should also

provide the basis for investigating existing contamination in the Columbia River by recording the existing knowledge of discharges to the river during the reactor operation period. The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector). DOE sites that will serve as long-term disposal sites could benefit from a mass balance inventory based on records, process chemistry, and uncertainty principles.

Current Baseline Technology: N/A

End User: Richland Environmental Restoration Project

References:

Agnew, S. F., et al., 1997, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model*, LA-UR-96-3860, Rev. 4, Los Alamos National Laboratory, Los Alamos, New Mexico.

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DOE-RL, 1998a, *Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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DOE-RL, 1999b, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, DOE/RL-98-72, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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B.5.2 Provide Method for More Accurate Estimates of Waste Constituent Release Rates and Modes from Waste (RL-SS42)

Program: Environmental Restoration

OPS Office/Site: Richland Operations Office/Hanford Site

Operable Unit(s): Broad need potentially applicable to multiple operable units.

Waste Stream: ER-14: LLW Soils 200 Area, ER-03: MLLW Soils, ER-04: LLW Soils 100/300 Area

Waste Management Unit: N/A

Facility: N/A

Priority Rating: This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

Need Title: Provide method for more accurate estimates of waste constituent release rates and modes from waste.

Need Opportunity Category: Technology Need

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

To conduct sitewide assessments of cumulative impact to the Columbia River and river-supported life, the rates of release from waste source terms are needed. Limited data are available on actual release rates. Hence, the primary technical gap is the need for models to describe release rates from all waste that will reside at the Hanford Site in the post-closure period. Thus, models and supporting data are needed for radionuclide and chemical releases from solid waste burial grounds, past tank leaks, future tank losses, tank residuals, proposed immobilized low-activity waste (i.e., glass), past-practice liquid discharge sites (i.e., crib, ponds, ditches, reverse wells, french drains, and specific retention trenches), canyon buildings (i.e., PUREX, B Plant, T Plant, U Plant, and S Plant), PUREX tunnels, the PFP building, and the graphite cores of production reactors. These modeling results provide temporal and spatial information for system assessments.

Specific issues include the following:

- It is anticipated that some residual waste will reside in the tanks after retrieval, consistent with closure criteria established with the regulators. The solubility/leachability of key constituents in these residuals and the behavior of the released contaminants at the waste-sediment interface is important for setting closure requirements and for estimating future quantity and composition of releases from the tanks and the subsequent impact of the releases. Technetium has been identified as one of the first contaminants to evaluate. It is often a performance assessment driver due to its solubility and mobility in its pertechnetate form. However, recent investigations indicate that much of the technetium may be in the insoluble non-pertechnetate form. It is important to determine the behavior of this contaminant under leaching conditions of tank waste residual and at the waste-sediment interface as it enters the vadose zone. Indeed, the actual release rates of technetium, selenium, and uranium (i.e., the major predicted human health dose contributors) from the tank residuals are essentially unknown. A fundamental understanding and capability to simulate releases from salt cake, sludge, and hard heal in Hanford Site tanks is needed (Technology Need RL-WTNEW02). This effort supports future studies of tank waste patterned after the Retrieval Performance Evaluation (DOE-RL 1999 [RPE]).

- Appropriate release rates from a soil-waste matrix near unplanned tank releases are also needed. The soils have been modified due to contact with high heat and high pH tank wastes, effectively producing a new "waste form." The rate of release from these areas to underlying soils needs to be determined through activities within Technology Need RL-SS28. The results from those studies will serve as a basis for developing the release model in this need statement. In addition to the release and mobility of past tank leaks that have formed a new waste form in the subsurface, it is important to develop the knowledge required to estimate the release and migration of waste that will follow past tank leaks. Future tank losses and tank residuals from the same tanks will have the opportunity to travel the same path within the vadose zone as the past tank leak. Thus, the influence of the initial leak on the original soil/sediment profile is important to understand as the basis of future releases and their migration and fate.

- In addition to residual tank wastes and the vadose zone environment containing past tank leaks, there is a need to develop, document, and obtain technical peer acceptance of a release models for virtually all wastes forms that will remain at the Hanford Site after closure. Release models for graphite cores were developed and applied in the Surplus Production Reactor Environmental Impact Statement (EIS) (DOE 1989, 1992). The RPP is developing release models for low-activity waste glass. Soil-debris models based on solubility and adsorption/desorption physics have been developed and employed for solid waste burial grounds, but may require peer review to document their acceptance. Diffusion-based release models and data are being developed for application to high-integrity concrete containers, but will require peer review before application in analyses supporting large-scale disposals in Hanford Site burial grounds. Conceptual models and supporting data are needed for several key wastes at the Hanford Site, including (a) the canyon buildings and their contents, (b) the PUREX tunnels, (c) the PFP facility, (d) ancillary piping throughout the chemical separations areas, (e) stack scrubbers for I-129, and (f) the past-practice liquid discharge sites. Some future wastes are still poorly defined, but will also require inclusion in a system assessment. These include secondary waste streams and waste disposals generated by the future chemical separation of tank waste into high- and low-level fractions, and the vitrification of wastes. Examples are radionuclides such as Tc-99 separated from both the high- and low-level fractions and returned to DOE for disposal, and failed melters from the vitrification plants.

Functional Performance Requirements: The techniques applied or information that is obtained must estimate containment failure and contaminant release such that the information can be applied toward the conceptual models, fate and transport numerical models, and site-specific and system assessment capabilities that are being developed as part of the Integration Project.

Schedule Requirements: The draft S&T Plan as outlined in the GW/VZ Integration Project Specification (DOE-RL 1998b) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with contaminant release into the vadose zone is needed in the FY99 to FY00 time frame to meet these objectives. A Hanford Site Tank Farm Closure EIS is presently scheduled for 2003.

Because of the variety of contaminant release models that need be developed, documented, and peer accepted prior to issuance of a regulatory decision-assisting system assessment, it may be necessary to schedule this activity over a longer time frame. Thus, scheduling peer review and acceptance of release models very near the time they will be needed to support the assessment (i.e., an environmental impact statement, a composite analysis will be needed), rather than requiring peer review and acceptance before the proposed models can be used in prototype simulations.

Problem Description: This need falls under the Inventory Technical Element within the S&T Endeavor. Inventory is defined as the total quantity of radiological and chemical constituents used and created at the Hanford Site, and their distribution in and release from facilities, waste disposal sites, the vadose zone, groundwater, and Columbia River ecosystem. The Inventory Technical Element is intended to address the need for estimates of radionuclide and chemical

contaminants that have been or are expected to be released to the Hanford Site soil column. Such an inventory would represent the total amount of selected radionuclide and chemical constituents at the Hanford Site and their distribution among and release from facilities, waste disposal sites, vadose zone, groundwater, and Columbia River. The objective of the Inventory Technical Element is to enhance protection of human health and environment by providing estimates of the location, amounts, concentrations, chemical form, and mobilization/release mechanisms of key inventory components, which provides the necessary input to sitewide subsurface system assessments. An implicit goal of this research is to provide scientifically defensible knowledge and data and identify existing and new S&T that will serve as input to DOE's decision-making process for Hanford Site cleanup.

The goals of the inventory technical element are largely twofold. First, a consistent approach and set of assumptions for providing information on waste site inventories across the Hanford Site needs to be established to ensure that a sitewide inventory data set is available for system-wide and project-specific impact assessments. Second, key chemical and radiological contaminants and soil sites need to be identified, and estimates of the amount and release characteristics of these key contaminants in different waste forms and storage/disposal areas (e.g., tanks, solid waste burial grounds, other) need to be validated.

A good understanding of inventory and release is key to a system assessment, because the potential groundwater and river contamination is proportional to the amount of radionuclides and chemicals that are disposed on Hanford Site and capable of migrating off the site. Technical information needed to determine inventory include 1) locations, amounts, and concentrations; 2) characteristics of the radionuclide or chemical compound; 3) mobilization and release mechanisms and rates; and 4) the change in inventory because of natural processes (e.g., decay), remediation activities, and Hanford Site operations. In addition to inventory estimates, mechanisms must be identified that result in release of the inventory from facilities into the vadose zone, unconfined aquifer, or the Columbia River. Because the long-term configuration of the waste inventory depends on future remediation and land-use decisions, a baseline estimate of end-state inventory distributions must be defined.

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Justification for Need:

Technical: Current waste constituent release models are not sufficient to estimate the mechanisms and rates of release for all Hanford Site waste types (e.g., solid wastes, residual tank waste, canyon and PFP buildings, PUREX tunnels, past-practice liquid discharge sites). These estimates are needed for quantifying potential source terms for contaminants.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions. Supplemental guidance to DOE Order 5820.2a, and draft DOE Order 435.1, require a Composite Analysis of all post-closure low-level waste (LLW) to estimate long-term all-pathways human health impacts. Thus, inventory and

release models for all post-closure wastes are needed. A Composite Analysis was completed in 1998 (Kincaid et al. 1998) and must be updated on a 5-year cycle. The Composite Analysis is a companion analysis to performance assessments for active and planned LLW disposals and remedial actions. Thus, continued disposal authorization at the Hanford Site requires that this the composite analysis be supported and periodically completed. Similarly, continued DOE-HQ support for records of decision for remedial actions requires periodic completion of a composite analysis. The Composite Analysis offers a real opportunity to first quantify and then investigate the issue of uncertainty, and the related issue of the value of additional data investments.

Environmental Safety and Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Cost Savings Potential (Mortgage Reduction): This need is targeted at obtaining information that will help develop a better understanding of the Hanford Site contamination. This understanding will be used to determine appropriate solutions to these contamination problems. These solutions may offer a cost savings potential over solutions selected based on the current, more limited knowledge of contaminant distribution and migration potential at the site.

A scientifically supported and peer-accepted compilation of containment failure and contaminant release models would be of great value to the Hanford Site and would establish a key element of several future analyses including EISs, performance assessments, feasibility studies, and composite analyses.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment*. (Stakeholder and Tribal Nation concerns about the completeness and consistency of the assembly of containment failure and contaminant release data and estimates are expressed in the CRCIA Part 2 document [DOE-RL 1998a]). The regulators, stakeholders, and Tribal Nations also expressed a strong interest in formulations of the system assessment that would quantify the uncertainty in future impacts.

Other: None.

Consequences of Not Filling Need: Completion of release models for all wastes based on available data and peer-accepted methods is essential to any sitewide or system assessment. Currently, there is no single and consistent suite of containment failure and contaminant release models for the disposal and remediation activities planned at the Hanford Site. This must include wastes in a post-closure setting in the 100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, 300, 200 West, and 200 East Areas. Because some of the sitewide analyses are required by DOE order, they will be completed even if the development of data-supported and peer-accepted release models is not. System assessments conducted without the supporting scientific work are completed and submitted at risk of being rejected. Rejection could impact DOE-HQ issuance of

approval for continued disposals (e.g., LLW disposal in solid waste burial grounds in 200 West Area, LLW disposal in solid waste burial grounds in the 200 East Area, and *Comprehensive, Environmental Response, Compensation, and Liability Act* [CERCLA] cleanup waste disposal in the Environmental Restoration Disposal Facility).

The activity that this needs supports is identified in the GW/VZ Integration Project Specification (DOE-RL 1998b) S&T Roadmap. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

Outsourcing Potential: The technical issues for this need are Hanford Site specific, but solutions to the need may have application broadly at other contaminated sites within the DOE complex and for other organizations (e.g., DOD, the private sector). DOE sites that will serve as long-term disposal sites (e.g., Hanford, Idaho, Los Alamos, Nevada, Oak Ridge, Savannah River) could benefit from an approved suite of release models for the many waste types present at and common to the various sites across the DOE complex. Such a compilation should address available data, alternate conceptual models, and formulations including uncertainty.

Current Baseline Technology: For many wastes, conceptual models exist. For others, conceptual models have not been formulated and are needed before system analyses can proceed. In some cases, including that of residual tank waste, a relatively simple model has been used in the past and a more realistic model or suite of models is needed now.

End User: Richland Environmental Restoration Project

References:

DOE, 1989, *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington; Draft Environmental Impact Statement*, DOE/EIS-0119D, U.S. Department of Energy, Washington, D.C.

DOE, 1992, *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington; Addendum (Final Environmental Impact Statement)*, DOE/EIS-0119F, U.S. Department of Energy, Washington, D.C.

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DOE-RL, 1998b, *Groundwater/Vadose Zone Integration Project Specification*, DOE/RL-98-48, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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Kincaid, C. T., M. P. Bergeron, C. R. Cole, M. D. Freshley, N. L. Hassig, V. G. Johnson, D. I. Kaplan, R. J. Serne, G. P. Streile, D. L. Strenge, P. D. Thorne, L. W. Vail, G. A. Whyatt, and S. K. Wurstner, 1998, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, PNNL-11800, Pacific Northwest National Laboratory, Richland, Washington.

B.6 RISK TECHNICAL ELEMENTS

Table B-6. Risk Technical Element Index to Linked Needs.

RL-SS43	Improvements to Ecological Risk Assessments and Analysis of Population-Level Impacts
RL-SS44	Improvements to Human Health Risk Assessments
RL-SS45	Establishing Technical Basis for Socio-Economic Risk Assessments
RL-SS46	Modeling Risk Knowledge

B.6.1 Improvements to Ecological Risk Assessments and Analysis of Population-level Impacts (RL-SS43)

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of water resources, including the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need summarizes a number of S&T components that together address a specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Techniques, technologies, and information that reduce uncertainty in current risk assessments and more directly address applicable ecological risk guidelines and regulations are needed to address ecological risks posed by contaminants at the Hanford Site. Current techniques and information are insufficient to predict accurately individual exposures to contaminants, especially where food chains and nutrient analogues are involved, and the effects from this exposure. Thus, conservative assumptions are required that increase uncertainty in the assessment results.

Besides requirements to understand exposures and effects at the individual level, guidelines and regulations are increasingly requiring estimates of risk to populations and ecological functions (Durda and Preziosi 1999). For example, regulations under the *Endangered Species Act* require

assessing individual risks for endangered species, as well as estimating risks for the survival of that species. However, there is insufficient knowledge to characterize population exposures to contaminants and the effects such exposure might have on population processes. Specific needs to address these technical gaps include the following:

- Exposure-related information needs
    - Exposure scenarios for specific species groups that are important to food webs at the Hanford Site (e.g., data on the relative exposure to surface waters and pore waters of benthic invertebrates in the Hanford Reach are not known, nor is the relative uptake from the vadose zone versus groundwater by deep-rooted riparian plants)
    - Toxicokinetic/toxicodynamic models to predict the body burdens of contaminants under spacio-temporally varying exposure conditions in multiple media
    - Methods to predict relative bioavailability of contaminants in multiple media for a diverse set of organisms
    - Methods to measure temporally varying exposures of aquatic organisms that use areas larger than the area affected by contaminants
    - Techniques to reduce the uncertainty associated with extrapolation of toxicological parameters across taxa
- Response-related information needs
    - Toxicokinetic/toxicodynamic models to predict effects of multiple Hanford Site contaminants on key species
    - Statistical methods and data to more accurately extrapolate responses measured in one species to responses in other species
    - Methods and data to estimate effects of exposures on populations and ecosystem processes, including direct effect approaches, population dynamics models, and ecosystem process models.

Functional Performance Requirements: The application of the knowledge gained through the performance of the specific needs must address the Hanford Site contaminants and species of interest. The information must result in a better understanding of the uncertainty in current assessments and address upcoming changes in guidelines and regulations.

Schedule Requirements: The S&T Roadmap indicates that the information is required to be implemented as part of the SAC, Rev. 2. In addition, information associated with key contaminants (e.g., Sr-90 and hexavalent chromium) in the aquatic environment are required for decisions associated with the remediation activities in the 100 Areas by the FY04 time frame.

Problem Description: This need falls under the Risk Technical Element within the S&T Endeavor. The Risk Technical Element will provide an assessment of the potential risks to the environment, human health, economic, and socio-cultural quality of life from Hanford Site-derived contaminants. Ecological risk assessments include four phases in the evaluation: problem formulation, exposure characterization, ecological effect characterization, and risk characterization (EPA 1998). This need addresses all four phases of ecological risk assessment, and the approaches for fulfilling the need will improve the accuracy, precision, and utility of ecological risk assessments at the Hanford Site and throughout the DOE complex.

Justification for Need:

Technical: There currently is insufficient information to address population-level impacts and specific toxicological data to support assessment of many Hanford Site species. In the absence of the information addressed in this need, there is high uncertainty in current ecological risk assessments.

Regulatory: This need specifically addresses EPA guidelines and upcoming changes to Washington State's *Model Toxics Control Act* on population-level risk assessments. The information obtained by addressing the need will provide an improved technical basis for making decisions.

Environmental Safety and Health: This need specifically addresses environmental safety and health issues across the Hanford Site.

Cost Savings Potential (Mortgage Reduction): This need will improve the accuracy, precision, and utility of ecological risk assessments at the Hanford Site. Cost savings can be achieved by focusing cleanup on regions where the greatest potential for ecological impacts can occur and justify where more restrictive clean up standards need to be applied to protect ecological systems.

Cultural/Stakeholder Concerns: This science need supports cultural and stakeholders concerns to address ecological impacts that were expressed in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998). Ecological risk information that is specific for the species that are of most concern are specifically addresses in this need.

Consequences of Not Filling Need: Ecological risk assessments are to be required for remediation decisions in the upcoming changes in Washington State's *Model Toxics Control Act*. These changes include impacts to populations. Without additional information to include in ecological risk assessments, the Hanford Site will not be able to address these new requirements.

Outsourcing Potential: The results have broad application to sites within the DOE complex and other organizations (e.g., DOD and the private sector); however, the needs do address contaminants and species that are specific to the Hanford Site environment (e.g., salmon, chromium, and Sr-90).

Current Baseline Technology:

End User:

References:

DOE-RL, 1998, *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Durda, J. L., and D. V. Preziosi, 1999, "Where's the Population in Your Risk Assessment?," *SETAC News*, November 1999, Society for Environmental Toxicology and Chemistry.

EPA, 1998, *Guidelines for Ecological Risk Assessment*, EPA/630/R-95/002F, U.S. Environmental Protection Agency, Washington, D.C.

B.6.2 Improvements to Human Health Risk Assessments (RL-SS44)

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of the water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need summarizes a number of S&T components that together address a specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Improved techniques and information that reduces analysis uncertainty are needed for human health risk assessments. This will increase the scientific defensibility, realism of the analysis, and comprehensiveness of the assessment. Improvements are needed in all four basic steps of human health risk assessments, hazard identification, exposure assessment, dose response assessment, and risk characterization (NRC 1983). Specifically, the technical needs include the following:

- Appropriate biological models and transfer factors to link plant-animal contaminant conditions to availability for human intake

- Reliable, reproducible biophysical measurement techniques that can provide quantitative indication of individual human exposures to key radionuclides and chemicals

- Incorporation of realistic retention/clearance and distribution information in the exposure assessment, and consideration of homeostasis and the behavior of mixtures and chemical analogs

- Modification of risk assessment methodologies to incorporate realistic exposures, dose response, and risk characterization for Hanford Site contaminants and regional lifestyles.

Functional Performance Requirements: The application of the knowledge gained through the performance of the specific needs must address the contaminants and human health scenarios that are applicable to the Hanford Site. The information must result in a better understanding of the uncertainty in current assessments and address upcoming changes in guidelines and regulations.

Schedule Requirements: The S&T Roadmap indicates that the information is required to be implemented as part of the SAC, Rev. 2. Information that improves health assessments, increases defensibility of the results, and provides a more comprehensive assessment is required for decisions associated with remediation activities for the next CERCLA review of Interim Records of Decision (~FY05 time frame).

Problem Description: This need falls under the Risk Technical Element within the S&T Endeavor. The Risk Technical Element will provide an assessment of the potential risks to the environment, human health, economic, and socio-cultural quality of life from Hanford Site-derived contaminants. Human health risk assessment includes the four steps mentioned above, and the needs address technical improvements in each step as well as modifications to the methodology to address Hanford Site-specific issues. The need addresses human health links to the environment, cultures and social systems. Fulfilling the need will improve the scientific defensibility, realism of the analysis and comprehensiveness of human health assessments at the Hanford Site and throughout the DOE complex.

Justification for Need:

Technical: There is insufficient information to support realistic, comprehensive human health risks at the Hanford Site. The needs address technical issues to increase the scientific defensibility of exposures assessments to the diversity of people within the region and dose response assessments of the complexity of contaminants at the Hanford Site. In the absence of the information addressed in this need, there is high uncertainty in current human health risk assessments.

Regulatory: This need addresses the desire of Hanford Site regulators to assess future human uses of the Hanford Site and upcoming changes to EPA guidelines and Washington State's *Model Toxics Control Act*. The information obtained by addressing the need will provide an improved technical basis for making decisions.

Environmental Safety and Health: This need specifically addresses environmental safety and health issues across the Hanford Site.

Cost Savings Potential (Mortgage Reduction): This need will improve the scientific defensibility, realism of exposure assessments, and comprehensive nature of human health risk assessments at the Hanford Site. Cost savings can be achieved by focusing cleanup on regions where the greatest potential for human health impacts can occur.

Cultural/Stakeholder Concerns: This science need supports cultural and stakeholders concerns to address human health and comprehensive impacts that were expressed in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998). In addition, this need also supports recent concerns expressed in the area of assessing alternative dose-response relationships to low-dose radiation effects.

Consequences of Not Filling Need: If these needs are not fulfilled, there will not be improvements to the human health risk assessment methodology at the Hanford Site. The issues that are brought up by decision makers, regulators, and the stakeholder community will not be addressed, and the credibility of human health assessments will remain the same.

Outsourcing Potential: The results have broad application to sites within the DOE complex and other organizations (e.g., DOD and the private sector).

Current Baseline Technology:

End User:

References:

DOE-RL, 1998, *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

NRC, 1983, *Risk Assessment in the Federal Government: Managing the Process*, National Research Council, National Academy Press, Washington, D.C.

B.6.3 Establishing Technical Basis for Socio-Economic Risk Assessments (RL-SS45)

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of the water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need summarizes a number of S&T components that together address a specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG

Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This need outlines improved techniques and information required for the inclusion of economic risk to the decision-making process. Economic impacts can occur directly from changes in human and ecological health due to exposure to contamination, or impacts can occur indirectly due to "ripple effects" from other impacts. Economic impacts do not result until risks are perceived. The first step is to determine at what point does the level of environmental risk begin to influence the behavior of people such as consumers, producers, recreational fisherman, and sailboarders, for example. The points, or trigger mechanisms, are then applied to examine how the potential exposure of the environment to Hanford Site-derived contaminants influences economic market and nonmarket behavior as well as social activities. Specific activities for this need include the following:

- Improved methods are needed to predict how residents, recreationists, consumers of agricultural products, and other stakeholder groups process and respond to information concerning risks posed by environmental contamination.

- Techniques and information that accurately quantify Columbia River-based recreation and other social values are needed to calibrate economic and health effects models.

- Process-oriented non-monetary cardinal and ordinal metrics need to be developed so that the competing preferences for nonmarket resources or alternative ecological scenarios for mitigation can be evaluated and ranked by the various stakeholder groups and a best alternative could be identified for each.

- Improved benefit transfer methodology for developing estimates of economic benefit associated with specific natural or nonmarket resources are needed.

Functional Performance Requirements: This need must provide the technical basis for trigger mechanisms in the economic risk assessment process.

Schedule Requirements: The S&T Roadmap indicates that the information is required to be implemented as part of the SAC, Rev. 2, and therefore needs to be completed by FY04. Information on improved methods for economic triggers should be included in the analysis for the SAC, Rev. 2, and therefore should be completed by FY03.

Problem Description: This need falls under the Risk Technical Element within the S&T Endeavor. The Risk Technical Element will provide an assessment of the potential risks to the environment, human health, economic, and socio-cultural quality of life from Hanford Site-derived contaminants. Economic assessments have begun to appear in EPA's publications on environmental decision-making (EPA 1999), and stakeholders have requested the inclusion of this information for their participation in Hanford Site activities (DOE-RL 1998). At this time there is little understanding of the triggers for economic impacts, and even less understanding of the non-market resource evaluations. This need addresses methodologies for better understanding economic risk at the Hanford Site and surrounding areas.

Justification for Need:

Technical: There is currently insufficient knowledge of how the potential exposure of Hanford Site-derived contaminants influences economic market and nonmarket behavior as well as social activities. This science need addresses collection of information to be used in future economic assessments

Regulatory: Economic assessments are indirectly related to regulatory requirements at the Hanford Site. Information obtained by addressing this need will provide more information for making site regulatory decisions.

Environmental Safety and Health: This need is indirectly related to environmental safety and health issues in that the consequences of activities that jeopardize safety and health will result in economic impacts.

Cost Savings Potential (Mortgage Reduction): Inclusion of socio-economic risk assessments in Hanford Site decisions will focus attention on the remediation activities that have the greatest reduction in risk to human health and the environment. The need will provide information that can be used in prioritizing remediation activities and negotiating sound cleanup standards. Cost savings will be achieved by providing sound technical basis to remediation and cleanup standards.

Cultural/Stakeholder Concerns: There is great concern in the stakeholder community to include economic risk in Hanford Site remedial decisions. This need addresses the social and economic assessment requirements that were expressed in *Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment* (DOE-RL 1998).

Consequences of Not Filling Need: By not filling the gap in knowledge associated with Hanford Site-derived contaminants and economic impact parameters, a high degree of uncertainty will be attached to the economic risk assessment results in the SAC. There is a clear indication that economic risk assessment will be used in decision making. Hanford Site stakeholders have indicated that economic risk is required for consideration in decisions about the site (DOE-RL 1998), and EPA's Science Advisory Board has included economic risk in a recent publication on uncertainty and decision making.

Outsourcing Potential: The results have broad application to sites within the DOE complex and other organizations (e.g., DOD and the private sector).

Current Baseline Technology:

End User:

References:

DOE-RL, 1998, *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

EPA, 1999, *Integrated Environmental Decision-Making in the 21st Century*, Report from the EPA Science Advisory Board's Integrated Risk Project, EPA-SAB-EC-99-018, Peer Review Draft, May 3, 1999, U.S. Environmental Protection Agency, Washington, D.C.

B.6.4 Modeling Risk Knowledge (RL-SS46)

Need Description: This need addresses specific technical gaps identified in the scope of the GW/VZ Integration Project at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions are defensible and possess an integrated perspective for the protection of the water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need summarizes a number of S&T components that together address a specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

Socio-cultural risk assessment methodology is just beginning to be addressed by risk assessors, risk managers, and decision makers. The methods and approaches are poorly defined at this time. Data-gathering activities are being defined and addressed in other endeavors within the Integration Project to collect preliminary information on identification of affected communities, understanding the environmental values of these communities, evaluating cultural landscapes, and performing quality of life studies. The scientific need is to collect this information into a model or models that can be used to integrate all risk elements in a form that communicates effects of the Hanford Site today and into the future with the concerned communities.

This need recognizes that knowledge is socially constructed. Successor socio-cultural studies will lay the epistomological foundation for understanding how the various affected cultural communities organize knowledge relative to risk. There is a need to take those findings and produce an integrated risk perception model. The model will be essential for finding common intellectual ground, which is essential for building partnerships in dealing with Hanford Site waste. The creation of these partnerships is essential for reducing risk uncertainty and bias. These partnerships should include all culturally affected communities and decision makers.

Addressing this need requires integrating findings from other social and cultural studies regarding the major variables and variable relationships that exist among the members of the concerned communities. The major research question to be addressed is the extent to which

these variously based community variables and relationships can be simultaneously modeled or whether they are mutually irreconcilable.

To address this need, one or more integrated risk models must be developed to serve as a foundation for explaining past community behaviors with regards to risk and predicting future responses to changes in the Hanford Site environment.

Specifically, the need is to:

- Develop integrated risk models that will serve as a foundation for explaining past community behaviors with regards to risk and predicting future responses to changes in the environment from the waste remaining at the Hanford Site upon site closure

- Develop tools for communicating integrated risk to regional communities and decision makers. These tools have to provide real-time response to the "what-if" scenarios that would be addressed in communication of risk at stakeholder/decision-maker meetings.

Functional Performance Requirements: This need addresses the integration of risks to the environment, human health, economic impacts, and socio-cultural impacts. The analysis must provide information on how affected communities relate to Hanford Site contamination. This information will be used by decision makers to focus remediation activities and stewardship responsibilities.

Schedule Requirements: The S&T Roadmap indicates that the information is required to be implemented as part of the SAC, Rev. 2. As mentioned above, there are basic data-gathering activities that must be completed prior to addressing this need. Development of the integrated risk knowledge models should begin shortly after the data-gathering activities identify the affected communities.

Problem Description: This need falls under the Risk Technical Element within the S&T Endeavor. Socio-cultural risk assessment is being addressed in the Integration Project because of a growing recognition that the conventional risk assessment paradigm does not address all of the things that are "at risk" in communities facing the prospect of contaminated waste sites or permitted chemical or radioactive releases. There is a need for developing integrated models to incorporate the information of concern to affected communities and provide tools that will be used to communicate the results of the model to them and decision makers.

Justification for Need:

Technical: There is currently inadequate understanding of how cultural communities in the region will react to Hanford Site contamination in the future. Improved information is needed to allow decision makers to better communicate the risks that might occur in the future.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety and Health: Safety and health are the primary concerns within modeling risk knowledge.

Cost Savings Potential (Mortgage Reduction): Addressing this need will only indirectly provide cost savings by providing better risk communication between the decision makers and the stakeholders.

Cultural/Stakeholder Concerns: The need directly relates to the cultural and stakeholder concerns of cleanup at the Hanford Site and the future of the site. The integration of their concerns within the overall risk communication process will assist in successful decision making.

Consequences of Not Filling Need: Socio-cultural risk will not be technically defensible without fulfilling this need. However, the need cannot be addressed until other characterization activities are completed.

Outsourcing Potential: The results have broad application to sites within the DOE complex and other organizations (e.g., DOD and the private sector).

Current Baseline Technology:

End User:

Reference:

BHI, 1999, *Groundwater/Vadose Zone Integration Project: Preliminary System Assessment Capability Concepts for Architecture, Platform and Data Management*, CCN 0512242, Bechtel Hanford, Inc., Richland, Washington. http://www.bhi-erc.com/vadose/sac.htm#info

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